RF Project 3527
Final Report

1

the
ohio
state
university
research foundation
1314 kinnear road
columbus, ohio
43212

THE UTILIZATION OF THE BEHAVIORAL SCIENCES IN LONG RANGE FORECASTING AND POLICY PLANNING

Volume I of II

Stuart J. Thorson
Department of Political Science

August 1976

Sponsored by
ADVANCED RESEARCH PROJECTS AGENCY
ARPA Order No. 2345-3D20

January 1, 1973 - June 30, 1976

Contract No. DAHC15-73-C-0197

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE UTILIZATION OF THE BEHAVIORAL SCIENCES IN LONG RANGE FORECASTING AND POLICY PLANNING		5. TYPE OF REPORT & PERIOD COVERED Final - Appendices, Vol. I 1/1/73 - 6/30/76
		6. PERFORMING ORG. REPORT NUMBER 3527 Final
7. AUTHOR(s) Stuart J. Thorson, et al.		8. CONTRACT OR GRANT NUMBER(s) DAHC15-73-C-0197
9. PERFORMING ORGANIZATION NAME AND ADDRESS The Ohio State University Research Foundation 1314 Kinnear Road, Columbus, Ohio 43212		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Proj. No. 1001/134 ARPA #2345-3D20
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Army Defense Supply Service - Washington (ARPA) Rm. ID-245, The Pentagon, Wash., D.C. 20310		12. REPORT DATE August, 1976
		13. NUMBER OF PAGES 816 pp.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

"Approved for public release; distribution unlimited."

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Decision-making; forecasting; policy planning; Saudi Arabia; oil; computer simulation.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Technical Reports which comprise this volume provide detailed documentation of the technical work accomplished under this contract (ARPA Contract No. 3527-A1, DAHC 15 73 C 0197). These reports were written throughout the period of the contract and were originally submitted as appendices to the various Semi-Annual Technical Reports. Substantively these reports treat the range of topics dealt with under this contract including the role of forecasting in foreign policy planning, an

(continued)

Block 20 (Continued)

evaluation of various analytic methods used in forecasting and policy planning, an evaluation of the utility of some of the major empirical studies of international behavior for forecasting and policy planning, and extensive treatments of the various components of the Saudi Arabian planning simulation.

Theoretical Underpinnings of the Event Data Movement

Warren R. Phillips
Department of Political Science
Ohio State University

March 1973
Project Research Paper No. 1

Paper prepared for delivery at the ISA Meetings in New York, March 13-17, 1973.

Prepared in connection with research supported by the Advanced Research Projects Agency, ARPA Order No. 2345-3D20, Contract No. DAHC 15 73 C 0197.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
Project for Theoretical Politics The Ohio State University 053 Administration Building	UNCLASSIFIED
	2b. GROUP

3. REPORT TITLE

"Theoretical Underpinnings of the Event Data Movement"

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Research Report # 1

5. AUTHOR(S) (First name, middle initial, last name)

Warren R. Phillips

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
July 30, 1973	56	117

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
DAHC15 73 C 0197	# 1
b. PROJECT NO. A.O. 2345-3D20	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited and production in whole or in part is permitted for any purpose of the United States Government.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Advanced Research Projects Agency Washington, D.C.

13. ABSTRACT

A review and critique of the international events literature is provided in this paper in an effort to assess the state of theorizing by those who employ international events data. More precisely the attempt is made here to establish what are the basic underlying assumptions accepted by those who collect event interaction data. The conclusion of this review is that while the substantive interests of event data collectors seems developed well enough to characterize this body of literature as comprising a field, the theoretical basis of the field remains largely lacking. Thus, there is a clear need for more work in the area of theoretical explanations. Both the scholar and the policy-maker must recognize that international events are or should be simply indicators of substantive concepts bounded with theoretical frameworks, indicators of their particular perspective of nations and the behavior between nations. Some possible avenues to further theoretical development are suggested.

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
National attributes						
Systems						
International events						
Foreign policy actions						

The Theoretical Approaches in the Events Data Movement

The purpose of this paper is to review and critique theoretical activity in the events data movement. The task is certainly not an easy one and it is made more difficult by the fact that the material to be reviewed stems primarily from a data movement and not a theoretically homogenous brotherhood. Nevertheless, the movement does exhibit some common elements which have a strong philosophic background. This paper will trace the historical roots of the events approach, review the current state of theorizing by those who use this data, and attempt to suggest a few potential avenues for further pursuit.

Alberico Gentili, a sixteenth century professor of law, is credited as the founder of modern thought about international relations. This attribution rests on his determination to examine international relations from a secular rather than a theological standpoint. His celebrated cry 'let theologians keep quiet about matters outside their province!' marks Gentili off sharply from his scholastic predecessors and signaled the advent of a new era. His position was that Plato, Aristotle and the followers of Justinian ethics give no account of the laws of war except with reference to the needs of their own states. Thus, while they did talk about the cause of war, prisoners, and slaves and some other topics relating to the subject of conflict, they considered them all from the standpoint of a particular state and explained them with reference to that state's requirements; for example, the status of a prisoner and his relation to the citizen. "It remains however, to investigate the intricate question, what the law is and how we shall prove that it is this or that. For obviously we must not only teach in the manner of Plato, but because of conflicting opinions we must also demonstrate it in the manner of Aristotle . . . " (Gentili, 1612, as quoted in Forsyth, et. al., p. 20). Gentili's position is that we cannot accept the Augustinian principle that the injustice of an adver-

sary makes wars just, (Augustine, On the City of God, i.v.). Instead, we must develop a set of principles based upon natural law which lay down the basis for interactions between nations.

Grotius (1583-1645) further developed the arguments of Gentili by looking at the character of the international society in which states are subject to restraint through law. According to Grotius, the restraints were a combination of rules, some of which--the laws of nature--are derived from man's rational and social nature which demands order and justice, while others--like the laws of nations--are based on the will and consent of states. The second laws, the laws of nations, according to Grotius, are to be discovered by studying the relations between nations. Methodologically, Grotius confused natural law appropriate for individuals with natural law appropriate for the relations between states. Vattel, in 1758, pointed out that the natural law appropriate for individuals cannot be directly applied to states.

> "There is no doubt that the existence of a natural law of nations, in as much as the law of nature is no less binding upon states, where men are united in a political society, than it is upon the individuals themselves. As an exact knowledge of this law cannot be had by a mere understanding of what the law of nature prescribes for individual persons. When a law is applied to different subjects it must be applied in a manner suited to the nature of each subject. Hence it follows that the natural law of nations is a special science which consists in a just and reasonable application of the law of nature to the affairs and conduct of nations and of sovereigns. All those treaties, therefore, which confuse the law of of nations with the ordinary natural law must fail to convey a distinct idea and a thorough knowledge of the sacred law of nations (Vattel, 1758, as quoted in Forsyth p. 89.).

But in addition to the law of nations which is deducible from certain principles of natural law, there is a much larger group of laws

which govern the relations between nations. These laws, potentially demonstrable from the behavior of nations, are not to be confused with the natural laws.

> "These three divisions of the law of nations, the voluntary, the conventional, and the customary law form together the positive law of nations, they proceed from the agreement of nations; the voluntary law from the presumed consent; the conventional law from the expressed consent; and the customary law from their tacid consent. And since there are not other modes of deducing a law from the agreement of nations, there are but these three divisions of the positive law of nations. (Vattel, ibid)

The voluntary, customary, and conventional laws of nations govern the relations between nations over the period of time in which it can be agreed that these positive laws exist. The problem becomes one of delineating these commonly accepted patterns of behavior between nations. All three authors argue that it is through a combination of historical chronology and philosophical introspection that we can come to know the laws which govern the way nations deal with each other. The attack on the earlier scholastics is not in the realm of statements about what we can know, but it is about how we can know the laws that govern the relations between nations. And it is in this position on how we can come to a better understanding of the positive laws of nature that the early secular movement in international relations shows great affinities to the current systematic group of international relations scholars. Consider the following two quotes from Morton Kaplan and Richard Rosecrance, advocates of the popular systems approach.

> Morton Kaplan: "The crux of the matter is whether regularities can be discovered which permit the organization of the materials of international politics within a simple framework of reasonable explanatory or predictive power." (System and Process in International Politics, New York, Wiley, 1957, p. 3.)

> Richard Rosecrance: "[The essential works of diplomatic and political history] could provide the raw material from which systematic characterizations could be derived." (Action and Reaction in World Politics, 1964, p. 5.)

This new philosophy of the systemicists[1] is indeed an old position traceable back to the very beginnings of modern international relations. And its solution is the modest proposal that we consider systematically the actions between nations in an attempt to delineate the voluntary, customary, and conventional ways in which nations deal with each other. Perhaps a distinction between the two groups is worth pointing out however. The early philosophers were interested in much more than simply understanding the normal modes of behavior: They were interested in describing a set of laws for the correct application of international relations principles to the international society. It is not clear that the fathers of the current systems approach are that ambitious.

To be sure, not all of the systemicists have moved to the events data approach. But many have. An early advocate of this approach was Charles McClelland (1961) who argued that we need more than a perusal of diplomatic history as written by historians. Their works suffered from at least their difficulties: (1) On the whole, historians had not been concerned to take particular note of reoccurring forms in the sequences of exchanges between nations. (2) The historians place too much emphasis on a search of motives of actors and the decision-making activities that occur within foreign offices; and (3) Published diplomatic history is not rich enough in the presentation of exact interaction sequences, rather it is the historian's research notes that current analysts would be interested in (McClelland, 1961, p. 191).

With special reference to crisis setting, McClelland argues that:

> "Without any reference to the setting of a crisis or to its larger meanings in the politics of international relations, the coding of events of a crisis in chains of interactions sequences makes possible the identification of patterns and the comparison of forms of crisis behavior. Almost immediately, inferences are drawn and labels for many kinds of sequences are brought to mind. In the due course of an analytical study, a mapping of the complete crisis from its dramatic initial 'input' events to its tailing off into the 'normalcy' of routine international relations becomes possible. Studies which are limited to such charting and immediate analysis will have value in putting historical data to new use and in developing limited explanations of an aspect of international behavior. The ambition is greater, however: We wish to cope with the matter of peace and war and with the problem of control. . . . (1961, p. 193).

Thus we can see that the events data movement is an attempt to systematically refine the collection and codification of the actions and reaction of nations with each other. It is an old basic idea that by studying the interactions between nations we can come to know what is customarily accepted behavior between nations. We can also make assumptions about the voluntary agreement to limit certain types of interactions to specific events or sequences of events. The major difference, some would argue, advance, in the events data collection over earlier chronicling of exchanges between nations is the quantitative nature of the current enterprise. This quantification makes for more reliable, repeatable and testable assertions. What underlies this approach is a desire to specify how national decision-makers tend to select types of action and reaction from an inventory of foreign policy outputs to meet different kinds of non-routine and routine international situations? Three basic assumptions can be identified in the events data movement:

a) The concept of foreign policy as a set of decisions by officials is adopted. This foreign policy activity implies actions which can be delineated.

b) The behavior of one actor towards another actor (foreign policy) is responsive to the actions of other nations and involves efforts to influence who the leaders of these nations will be, what decisions they will take, and how they will define the relations between their nation and others.

c) Foreign policy is made in an environment by decision-makers who have mixed desires and domestic constraints to cope with. Their activity is essentially a process of adaptation to the external and internal environment which they seek to coordinate in an effort to maintain the autonomy and the sovereignty of the nation-state.

Certainly this perspective demands that we look at the patterns of action and reaction between nations and therefore systematic data collection efforts such as WEIS, DON, and MECCA have a justification in the search for the positive laws governing the relations between nations.

On a still more abstract level it is argued that national decision-makers consciously choose policy which may affect the overall patterns of cooperation and conflict in the international system. This type of explanation generally assumes that there is at least one individual within the nation who understands the dynamics of cooperation and conflict in the system. Who knows how other statesmen and his own constituents will react to a given policy and who uses this knowledge to get around the constraints which these reactions impose. This is the argument made by Stanley Hoffman (1968) in his delineation of roles in American foreign policy. It is also the type of argument made by William Langer in his discussion of the policies and motivations of Otto von Bismarck (1931).

As is the case with any new movement more time has been spent in specifying the relations between nations, the foreign policy actions and responses, than in coming to grips with the explanatory assumptions which

are also attributable to this approach. Let us begin by describing the current approach and findings emerging from the purely inductive studies which form the basis of work in the events movement.

The Description of Foreign Policy

Every act of a nation can be considered as a potential piece of information communicating to other nations the intense desires or dislikes of the acting nations. In addition, the variety of behavior is itself an important aspect of the study of event interactions. If the multitude of international behaviors are structured into a basic set of patterns, the variety of international interactions can be shown to reduce to the knowledge gain from each of these patterns of behavior. If, for instance, the behavior of nations reduces to five basic patterns, then there are five areas in which information is being transmitted. The class of nations exhibiting frequent behavior in one pattern is not likely to be the same class of nations participating extensively along other patterns. In adapting this approach, researchers have rejected the notion that international behavior can be measured by a single indicator. Such indicators represent only aspects of behavior, although important ones perhaps. They are looking for dimensions of behavior that are found to be independent of each other and searching for the smallest number of dimensions that accurately describe the variety of behavior between nations. Given the difficulty of using single variable indices for any one concept, i.e., poor data with unknown sources of error--random and systematic--in validity problems of the definitions, students of international relations are faced with a situation similar to Heisenburg's Indeterminacy Principle in Quantum Physics.[3] They cannot measure the precise position or charge of

the nation in the system. Instead, they have moved to methods that deal with probability densities--that define stable structure among arrays of behavior. In those areas where several variables tend to provide dense clusters of information, they are most likely to find the best measures for describing international behavior.

A number of specific questions guided this form analysis: (1) What are the dimensions of variation among nations with respect to their dyadic behavior over a continuous series of time points, (2) What is the relationship of these dimensions to those dimensions found by studying other time slices; (3) What are the groups of nation dyads that exhibit similar conflict behavior over time, and (4) What are the profiles of each group's conflict behavior?

Current research efforts have concentrated quite heavily upon analyzing the patterns of behavior in events data. Previous work has provided a good deal of information about behavior between select pairs of nations over time (McClelland et al (1965), McClelland (1968), North, et al (1967), Smoker (1967), Burrowes (1970), and Azar (1970)) or for all nations at single point in time (Rummel (1967) and Tanter (1966)), and to combine the longitudinal approach of case studies with the all inclusive approach of the cross-sectional studies (Phillips, 1969).

Perhaps the most significant finding of this research is the similarity in the dimensions between all such studies. The implications of this similarity are that the parameters which identify patterns of behavior over time do not change when the length of a time slice is varied. This should enable the calculation of pattern scores employing any time frame once the weights (factor loadings) were known from a single study with the results that realistic patterns of behavior would emerge.[4]

Comparison between different points in time tends to confirm the fact that the patterns of behavior remain quite stable. It appears to be the case, however, that while the patterns,or strategies of behavior, remain constant from one point in time to another the behavior of individual dyads are not predictable using simple linear transformations from one point in time to another (Rummel and Hall (1965a & b), Phillips and Lorimer (1972), and Burrowes at al (1972)). These findings ought to confirm the philosophically strong position that it is highly unlikely that a nation's behavior is a simple function of time. Thus, simple extrapolation techniques, while likely to be accurate in short range forecasting (Young, 1970a) are not likely to provide good predictions for longer term behavior performance.

Several attempts to provide taxonomies for classifying nations have been suggested (Rosenau and Hoggard (1971), Phillips (1969), Young(1970b)). While a number of taxonomic attempts have been made based either upon grouping nations according to behavioral similarities (Phillips, 1969) or grouping of nations according to attribute characteristics (Rosenau and Hoggard, 1971) to data no single taxonomy seems to be firmly grounded in theoretical expectations and sufficiently well accepted by members of the movement to command complete acceptance.[5]

It is quite clear that the early forefathers of this approach to describing positive relations between nations had in mind much more than the delineating of patterns and the classifying of actors or typing of nations. They wanted to use these general patterns to delineate the basic material from which philosophical introspection would produce universals for explaining and prescribing the relations between nations.

McClelland in the quote provided earlier has suggested the same thing. A prevalent strategy in the events movement has been the delineation of a set of patterns such as those discussed above and then the search for other variables which correlate highly with these patterns. Unfortunately Brunner (1970) has demonstrated very convincingly that the data analysis strategies presently employed by political scientists (such as correlation and regression analysis) will usually not reveal the underlying structure of a theoretical system. This will be the case regardless of whether the systems are analyzed cross nationally at a point in time or individually as a time series. Thus, there are several important problems facing analysts in the explanation of foreign policy exchanges. First, there is the very broad data analysis problem. To what extent can data--even time series data--be used to identify the basic structure of a theory of international interaction? Since most analysts' strategies cannot be used to distinguish between the structure of a theory and the parameters in that theory, it is the responsibility of the analyst to impose a basic structure on his observations prior to statistical manipulation.[6] Cain and Watts point out, "Without a theoretical framework to provide order and rationale for the large number of variables, we have no way of interpreting the statistical results." Regression and correlations analysis is properly used to estimate parameters for a model only when the structure of that model and the elements which make up the theory are already well specified. This specification of the structure must precede the application of statistical techniques" (1970, p. 229).

The reader may wonder by this time why introduce the analogy to Gentili and other early secularists? The answer is really quite simple.

Sorokin (1956) has suggested that two of the most serious ills that can befall a social science are the cult of Columbus syndrome and the malady of amnesia. He points out that too frequently, social scientists have been willing to suggest that what one is about to read in an article is a Brave New World discovered, thereby claiming to have discovered something for the first time and ignoring--hopefully unintentionally--previous work on the same problem by others. These are dangerous ills which can befall any science. They are dangerous, not because they cause personal animosity--"Why wasn't I cited?"--but because they cause us to waste time with concepts, approaches, or theories which have already shown to be arid and fruitless.

Classical international relations has shown that what is needed is a set of expectations based upon the interaction between nations. But they have also shown that much more is necessary than onthological discussions about how we can know (natural law versus positive law). They have demonstrated that a charting of what has transpired between nations is not enough. Rousseau advanced the deductive theory of the nature of the relations between nations and the essential state of war which exists. Authors such as Brougham and Gentz suggested that we could recognize underlying principles in the exchanges between states which guided their behavior such as the balance of power. To be sure, there are attempts to pursue the deductive approach to a comprehensive theory about the relations between nations as well as attempts to discern underlying universals in the study of relations between nations in todays literature. But far too much time is spend in the realm of ontology (Rogowski (1968), Levi (1969)) or in the charting of patterns. These

chartings are certainly an interesting early attempt to demarcate the boundaries of performance for any new set of concepts. That is perfectly legitimate and probably to be encouraged. But as classicists found out we must quickly move on to answer or attempt to explain some of the underlying problems which face students of international relations today.[7]

A survey of current theoretical attempts to explain foreign policy actions or situations using concepts which could be operationalized by event data point to two specific schools of thought, a systems school and a national attributes school. Both paradigms are not well developed in terms of a formal theoretical system. The components of each paradigm include some discussion of the basic unit of analysis, the organizing concepts and a dominate inferential pattern, but they do not tend to provide a complete delineation of the structure of their system. Nor do they frequently proceed to the state of deducing theorems or propositions from a set of universal statements. To articulate a largely implicit framework as an explicit system it is necessary, of course, to caricature. But it is hoped that this caricature can be instructive

The Systems Approach

One of the early advocates of the systems approach to international interaction was Charles A. McClelland. He suggested that once the relations of international politics were broken down to their most elementary form they take on the basic patterns of Figure I. It follows that the facts of international relations can be selected and organized according to the two references of actors and interactions (McClelland (1966), p. 18). For McClelland, interaction analysis or demand response pattern analysis has a preoccupation, tracing the resulting patterns and trajectories of

actions. He suggests that national systems have access to only a limited inventory of demand response actions in coping with the situations produced by system disturbances. How the government of a national system tends to select types of actions from the inventory to meet different kinds of non-routine international situations provides evidence of its operational code in international politics (1966, p. 105). Recently several theorists have underscored the importance of considering the total interactions, especially those between antagonists. Burton (1968) asserts that the progression towards war depends upon the equal contributions from both sides, each being governed by perceptions of threat. North and his colleagues assert that war may occur in a number of ways, but the chances of its occurrence are increased by the hostility in the atmosphere of crisis generated by the joint exchanges of the parties involved (1968). Zinnes has been concerned both with the expression of the hostility and with its perception and the ensuing responses (1968). The authors all emphasize the process of exchanges that underscore the symmetric importance of both participants and actions. Thus the flow of foreign policy exchanges between nations has certainly been the topic of much discussion, debate, and analysis. It has infrequently been the target of formal theoretical development, however. One of the more important aspects of the above literature is that it tends to mix prescription with description. Since this is the case, prediction is often dependent upon the effectiveness of role-playing. This principle is well recognized in administrative theory: Administration is not unlike play acting. The task of the good actor is to know and play

his role, although different roles may differ greatly in content. The effectiveness of the performance will depend upon the effectiveness of the play and the effectiveness with which it is played. The effectiveness of the administrative process will vary with the effectiveness of the organization and the effectiveness with which its members play their parts (Simon, 1958).

The task becomes one of constructing a theory of foreign policy which would be more than a set of normative rules for good diplomacy. Specifically, how could one construct an empirical theory? This is especially difficult in human systems (frequently termed artificial systems) where we are faced with an inability of the system to adapt perfectly to its environment (Simon, 1969). Let us begin with several rather simple automatic reaction models. The first is a no-lag immediate reaction to the foreign policy behavior received from another nation. This simple model follows closely with the work of Lewis Fry Richardson (1960), and his contention that the rate of change and hostility of one nation towards a second depends upon the level of hostility which the second harbors towards the first. This idea has been generalized by Dean Pruitt (1969) with the introduction the concept of reciprocity. "Change in one party's level of output on the same or another dimension." (Emphasis added; note that to be considered reciprocal in this use the behavior need not be of the same type or magnitude as that received.) To further develop this approach to the explanation of foreign policy outputs, consider the competitive international environment in which the nation

operates. The behavior of one actor towards an object state is in part a response to the strategic problems which that actor faces with respect to its object, goals, and activities. The actor's behavior is considered in its attempt to affect the object nations future behavior. These thoughts can be expressed in the following statement: An actor's behavior towards a specific object is a function of the behavior which it receives from the object; more simply put, behavior begets behavior. Mathematically this statement is represented by the following equation:

$$B_{nq,m,t} = \sum_{m=1}^{p} \alpha_m B_{qn,m,t} + G, \tag{1}$$

where

$B_{nq,m,t}$ is the behavior of nation n directed toward nation q on dimension m at time t;

$\sum_{m=1}^{p} \alpha_m B_{qn,m,t}$, is the weighted sum of each of nation q's behavior toward n as measured, respectively, along the p dimensions of behavior. The weights (α's) used in computing the sum are the relative importance of nation q's behavior, on each dimension, in influencing the behavior of nation o on dimension m;

and G is the projection, on dimension m, of the general level of activity which n holds toward q regardless of q's initiatives.

This equation states as a working hypothesis an actor's behavior results from the patterns of actions of its object. Tests of this statement (Phillips, 1971, 1972) tended to confirm its assertion. Other works in international relations (Tantar (1972), Bartos (1966), Azar (1970)) suggest similar hypothesis.

This can be called a tit for tat model of the relations between nations. But international relations must certainly be more than a tennis match in which each actor's response is to his object's service. There are forces at work over time within a nation which work to insure specific strategies be employed when dealing with specific object nations. Halperin suggests that "most of the actions taken by bureaucracies involve doing again or continuing to do what was done in the past. In the absence of some reason to change their behavior, organizations keep doing what they have been doing" (1970, p. 9). Bureaucratic inertia, as an explanation of performance in organizations, is appealing and leads to the working hypothesis that a nation's behavior in foreign policy results, in part, from its own prior patterns of action. Stated formally: a given nation's behavior toward a specific object is a function of its previous behavior toward that object. Mathematically this can be translated into the linear equation:

$$B_{nq,m,t}, = \alpha_m B_{nq,m,(t-1)} + G \tag{2}$$

where the symbolization is identical to the first equation and t-1 is a time period earlier. Combining the two approaches together to form a single equation:

$$B_{nq,m,t}, = \alpha_m B_{nq,m,(t-1)} + \sum_{m=1}^{p} \alpha_m B_{qn,m,t}, + G \tag{3}$$

But the meaning of the individual terms remains the same as to the two preceding equations, the new equation expresses mathematically the contention that foreign policy dynamics are powerfully influenced by both bureaucratic inertia and reciprocity.

McClelland (1961) suggests that the workings of a modern foreign office resemble the day to day operations of a well run industrial plant. Following this suggestion, we may develop the tit for tat models somewhat further. Multitudes of difficulties and problems would be received and dispatched in the daily flow by specialists in handling foreign affairs. To cope with this complexity, experts reassign responsibility for monitoring the exchanges with specific countries. The ability of these experts to deal with their assigned tasks is in part a function of their understanding of the intent underlying the patterns of behavior which are admitted by object nations in response to various behavior received during a given time period. In order to know the appropriate response to make to an object nation, the experts must be able to understand clearly and unambiguously the messages which they are receiving from that object.[8]

Thus diplomacy is communication as is the activity of the military and intelligence network. The transmission and reception of information is a major feature of the behavioral exchanges between nations. However, the amount of information conveyed between nations during the period of time must depend upon both the number of signals transmitted from nation to nation and the amount of information per signal transmitted. Approaches have been developed to measure and account for both the variety of signals transmitted and the amount of information transmitted.

One may count the number and types of signals which are sent from one nation to another. The heterogeneity of these signals at any point in time is a measure of the uncertainty which would attend any attempts to specify the sending selection processes (Cherry,(1957), Shannon and Weaver (1949), Ashby (1952)).

Information theory provides an excellent measure of the uncertainty, h, present in a set of signals;

$$H = \sum_{i=1}^{N} - P_i \log_2 P_i$$

the P_i symbol is the independent probability of the occurrence of signal type i , where there are n types of signals. Thus, from the probabilities P_i of different types of signals occuring in a given time period (same month), the uncertainty associated with the score for that period can be ascertained. If all outputs are equally likely, uncertainty is at a maximum. It is common to divide the actual uncertainty by the maximum value, deriving as a result the percentage of (maximum) uncertainty, which is more easily comparable across sources with differing sets of signals.

The work of Charles A. McClelland (1965, 1968, 1973) has shown that relative uncertainty values in excess of .700 signaled the threshold of a crisis. He has shown that the mix of behavior types does indeed change in a crisis toward greater variety. The literature on communications in international relations argues that in periods of crisis, system overload occurs and actors display an inability to respond consistently to their foreign policy inputs (Holsti (1965), Burton (1968)). It seems to be the case that in periods of relative uncertainty less than this level (.700) the higher the relative uncertainty the more reciprocal the response (Phillips and Crain (1972)).

Other studies have attempted to analyze the intent or the amount of information in an event. In order to check for the relationship between the intention of a message and the interpretation of the message,

the Stanford study group extended McClelland's original two actors in the reaction model. They state:

> "We are interested not only in what national decision-makers perceive or say they perceive about themselves and others. We are also interested in what they actually do. How are these perceptual and actional elements to be brought together systematically and correlated for meaningful analysis? Basically, we are interested in the international 'communication' in the sense that this communication can be used to characterize all transactions between nations. This indicates that both the verbal and the physical acts have information potential. The acts of one nation can be considered as inputs to other nations. The basic problem is this: Given some input to a nation, what additional information do we need to account for the nation's foreign policy response? (1968, p. 133)

Primarily those studies examined the 1914 crisis and compared perception with action (Holsti, North, and Brody, 1968), the expression and perception of hostility (Zinnes, 1968), and the conflict spiral of increasing hostility (North, Brody, and Holsti, 1964). The analysis of the Stanford group has also contributed information on the Cuban Missile Crisis (Holsti, Brody, North, 1964), the Sino-Soviet Debate (Holsti, 1965 and 1966) as well as the public pronouncements of John Foster Dulles (Holsti, 1962).

The above leads to the conclusion: In terms of the frequency or intensity of threats or action, when a state perceives itself to be the object of another's hostility, it identifies and expresses hostility toward the offending state. The perception of hostility seems to require both communications and actions. This relationship is tempered, however, by the degree of involvement in a conflict. Highly involved nations tend to exaggerate the amount of hostility being expressed toward them.

Thus, the m[illegible] involved the nation becomes in conflict the more sensitive it becomes, even over-estimating the intended hostility from the environment.

A few studies have attempted to add intervening variables to this basic communication model. Time has been considered an important situation variable such that when time pressures are great, decisions must be made more quickly without considering multiple alternatives (Holsti, 1965). The pressure of domestic events has also been hypothesized as an important instrument or force in influencing a nation to over or under respond to the receipt of behavior (Phillips, 1973). Third party actions are also considered as influencing the action and reaction model that has been set out here. At the data collection level Hermann and Salmore point out the need for considering the indirect object of a behavioral action (1970). Phillips and Hainline (1973) have studied the secondary impact of actions or the stimulus response models developed here for the triad, Soviet Union, United States and China.

All the work discussed to this point has two specific characteristics in common. They are all based upon linear equations and they are all determinant in nature. The former condition raises an empirical problem and the latter state of affairs raises the question of the specificity of theoretical work in this area. Linear equations assume that, in the simplest case of equation (1) a nation will respond to the inputs of another nation with the same strength of response throughout the range of the frequency of inputs. Thus, the sensitivity to a single threat from one nation to another is identical to the sensitivities to a hundred threats in a given time period from the object to the actor. Perhaps more importantly there

is no possibility for a change in the importance of the parameters over time. For instance, the relations between two nations may be based upon historical feelings of animosity which, because of a recent change in the relations between the two nations or because of a change in the domestic type of government of one nation, may have undergone a change which effects the ways in which the two nations interact. More simply, the recent past may provide important changes in the likelihood of certain forms of reaction in the present period. Karl Deutsch (1968) suggests that the highest of a nation's basic functions is its ability for self-transformation: "To respond to events in its environment in new ways, or at least in different and more rewarding ways" (p. 17). Burton (1969) argues states as political systems operate within an environment of other states to which they are adapting and responding: National interests are not fixed goals and include their adaptive processes (p.10). Laying aside for a moment the difficult task of defining national interests, the notions of adaptation and response do suggest that the actions of nations are based upon expectations of future responses gained by experience in the past of dealing with an environment which can most certainly be differentiated into objects of behavior. Holsti, North and Brody share this view:

> "Especially, then, it is by projecting past event into the future that human beings make decisions; and statesmen, in this respect are not exceptions. Foreign policy decision, like other human decisions, imply not only an abstraction from history, but also the making of 'predictions' --the assessment of probable outcomes. These two operations may be understood almost unconsciously, but they are nonetheless real and inescapable. The Marshall Plan was based upon a prediction, derived from some combination

> of experience, that systematic aid to European nations would bring about certain consequences. Viewed in retrospect, this prediction seems to have been generally sound. The basic prediction inherent in Khrushchev's decision to establish long-range missiles in Cuba, on the other hand, was much less accurate (1968, p. 125).

All too frequently, analysis of the processes of demand and response patterning has led to conclusions about the tendency of a lock-in effect.[9] Whether the process tends to adjust in certain issues and lock-in in others has yet to be discovered. In any event, it can be argued that the long series of crises since 1946 is part of this process of experimenting with new politics of international relations.[10] Without reference to a setting of the relationship or the larger meaning of politics in international relations, a theory may be developed which attempts to predict the future patterns of interaction and to compare the forms of the patterns of behavior between nations.

Since 1967, Rosenau has been advocating work and development on an adaptation paradigm. McGowen, (1970) has taken some of these notions and attempted to formalize them in a mathematical theory which takes into account the notions of adaptation previously suggested by Rosenau. McGowen states that:

> "In his most recent exploration of the adaptation paradigm, Rosenau argues as follows: First, 'Considerable insight' can be gained from viewing national societies, like the cell in an organism, 'as entities that must adapt to their environment to survive and prosper. That is, if an entity is to maintain the boundaries that separate it from other entities it must act toward the other entities in such a way to keep its essential structures intact (Rosenau, 1970, p. 2).' Second, for a national society 'adaptation means that fluctuations in the basic interactions patterns that sustain its social, economic, and political life must be kept within limits minimally

> acceptable to its members (Rosenau (1970) p. 2).' <u>Third</u>, since there can be considerable disagreement over what are acceptable limits of variation in the performance of a society's economy or policy, the politics of national adaptation is infused with 'an intensity and drama unknown to other entities' and processes (Rosenau (1970), p. 2). <u>Fourth</u>, the performance of essential societal structures is conditioned by external environment is a basic source of variation in its essential structure, 'the need for foreign policy rises--out of the fact that the essential structures cannot be kept within acceptable limits unless some kind of behavior is undertaken toward the environment (Rosenau(1970) p.3)."

The problem now becomes how to encompass the notions of adaptation and/ a learning into our expectations of the way nations interact. At least two possibilities are immediately recognizable. The one is the development of a learning theory for how nations continue to change and adapt their relations and the second is the development of control theory and its application to the process of adaptation of nation-states.

<u>Mathematical Learning Theory</u>

Mathematical learning theory has been developed to understand such tasks as signal detection and two person interaction.[11] The basic notions seem ideally suited for formalizing the dynamics of the processes developed in equations (1-3). One of the most applicable models has been developed by Rainio (1968). Rainio's basic idea for constructing a stochastic model is to consider social interaction as a process derived from the learning of the individuals participating in it. The fundamental assumption underlying his model is that a sequence of behavior is a series of choices between various alternatives, and certain probabilities are associated with the choice of the behavior alternatives by the mathematical law developed by Bush and Mosteller (1955). The purpose of his model is to

find in each particular choice situation the probabilities from which the choice between the alternatives is taken.

The social interaction process is assumed to take place according to the following model.

1) Social contacts may occur between the individuals under consideration, the number of whom is limited.

$$G = X_1, X_2, \ldots X_6$$

2) The individual who makes the contact is determined by a vector involving the probabilities with which each individual occurs as the contacter; the sum of the probabilities involved in the vector is unity.

$$K = \begin{matrix} P_1 \\ P_2 \\ \vdots \\ P_6 \end{matrix} \qquad . \quad \sum_{i=1}^{6} P_i = 1$$

3) The individual with whom the contact is made is determined by a vector that involves the probabilities with which each individual occurs as the contactee when the contacter is determined. thus there is one such vector for each individual and the probabilities in each vector add up to unity.

$$I = \begin{array}{c|llll} & X_1, & X_2, & \ldots & X_6 \\ X_1 & P_{11}, & P_{12}, & \ldots & P_{16} \\ X_2 & P_{21} & & & \\ & \vdots & & P_{ij} & \\ X_6 & P_{61} & & & P_{66} \end{array} \qquad \sum_{j=1}^{6} P_{ij} = 1$$

4) Once the individual who makes the contact with the individual with whom the contact is made have been determined, the contact is always realized with the probability 1.

5) When a contact between two individuals is realized, each one experiences the behavior of the other as A or $\bar{A}$, and the perception corresponds to the behavior of the individual concerned.

6) The behavior of the individual in the manner A or $\bar{A}$ in connection with the contact is determined by the probabilities P_A and $P_{\bar{A}}$, which add up to the unity.

7) A contact is always either rewarding or punishing to the individual.

8) If the contact is rewarding, the probability of making contact with the same individual increases according to the mathematical law $P_{n+1} = P_n + \alpha (1-P_n)$ involved in Bush & Mosteller's learning model. If the contact is punishing the probability of making contact with the same individual diminishes according to the mathematical law $P_{n+1} = P_n - \beta P_n$.

9) If the contact is rewarding, the probability of behavior in the same manner as in connection with this contact increases according to the mathematical law mentioned under (8), and if the contact is punishing, the probability diminishes correspondingly according to the second law presented under (8). (However, the coefficients α and β need not be the same as those employed in the transformations dealt with under (8)).[12]

Revision of Rainio's Model

The applicability of Rainio's model to the field of international relations seems to be restricted by his assumption mentioned under (8), i.e. both $A_i\ A_j$ and $\bar{A}_i\ \bar{A}_j$ were defined as "rewarding" to both i and j When we attempt to explain relationships between i and j in terms of their common views about a third individual k who is not participating in the interactions between i and j, Rainio's identification of rewarding contacts with common opinions seems to be meaningful.

But when the relationships between i and j are to be explained in terms of their direct behavior toward each other, Rainio's definition of rewarding contact provides an untenable result. For instance, the uncooperative behavior of i and j toward each other can be defined as rewarding contact by Rainio's definition. But we cannot think of mutually uncooperative behavior as rewarding to both i and j. Therefore, we need to modify his model to make it applicable to the study of international relations.

A revised definition of rewarding and punishing contacts between i and j might be:

$A_i\ A_j$: rewarding to both i and j

$A_i\ \bar{A}_j$: punishing to i and rewarding to j

$\bar{A}_i\ A_j$: rewarding to i and punishing to j

$\bar{A}_i\ \bar{A}_j$: punishing to both i and j

A_i : favorable behavior of i toward j

$\bar{A}_i$: unfavorable behavior of i toward j.[13]

Such a model could provide the basis for Monte Carlo simulations of the interaction between nations. The learning goal in this model is

to maximize the rewarding actions received from the environment. Such a model is being developed at Ohio State University for both teaching and research exercises. The impact of relative uncertainty, third party interactions, domestic events and the level of the bureaucracy involved in a decision to act are all being considered as having an impact upon "learning" in the model.

Such a procedure allows for the development of a microanalytic model which can serve as a hypothetical real world. Computer simulation of such a "world" can be employed to generate aggregated data for selected intervals of time. The data generated from such an experimental situation is not employed as a model of reality but a reality to be modeled. The history which is generated is designed to test hypothesis about real foreign policy interactions which have been adapted to this artificial world.[14]

Hierarchical Control Theory

Recent attention in theory and research on the bureaucratic handling of foreign policy questions has focused upon dealing with problems of the transfer of knowledge to action, criticizing policy, and describing governmental behavior. Finding a mutually agreeable approach to understanding the bureaucratic decision-making apparatus is difficult, however. Allison has underscored this problem: " . . . bureaucracy is the least understood source of unhappy outcomes produced by the U.S. government. Calls for the elimination of bureaucracy are, however, non solutions. Large organizations that function according to routines, and politics among individuals who share power, are inevitable features of the exercise of public authority in modern society" (1971, p. 265).

The United States experience in recent years suggests that the relationship between foreign policy decision-making on the one hand and information collecting and forecasting on the other is an integral aspect of effective organizational performance. The process suggests that there are patterns of behavior which are strongly influenced by organizational position and expectations. Hilsman, for instance, describes organizations in terms of the network of interpersonal relations at various levels (1971). There seems to be a recognized agreement between policy makers and academics on the existence of levels of behavior, on the interaction of motivation and goals, and of the impact of perceptions on preferred modes of action at different levels of the policy process. Some of the elements of these concerns can be made explicit if we introduce modern systems theories which seek to treat organizations as hierarchical multi-level control systems.[15] The concept of a multi-level, hierarchical structure cannot be defined by short, succinct statements. What I propose to do at this point is to 1) introduce some basic concepts for classification and study of hierarchical systems in general, 2) provide a conceptual foundation for the problem of coordination and 3) indicate some features of hierarchical systems which make them attractive for use in the study of foreign policy decision making.[16]

To begin with, the total system can be designated as the simple schematic in Figure 2. The ongoing process is that of foreign policy inputs and outputs: events. The operation of a subsystem on any level is influenced directly and explicitly from the higher levels, mostly from the immediately superseding level. This influence, while not always binding, tends to reflect a priority of importance in actions and goals of the higher levels. This influence will be termed intervention. The

priority of action is oriented downward in a command fashion, but the success of the overall foreign policy system and indeed of the units on any level depends upon the performance of all units in the system. Since the priority of action tacitly assumes that intervention precedes the actions of lower units, the success of the higher units depends upon that action or the resulting performance of the lower level units. Performance can be viewed, therefore, as feedback and response to intervention. Feedback is oriented upward, as shown by the upward arrows in Figure 2. I have termed these upward arrows the performance feedback channels. The layers that have been laid out can be broken down into functional decision hierarchies. The functional hierarchy should contain three layers as shown in Figure 3. The lowest level, the selective level, accepts the information from outside the unit and applies a decision algorithm to derive a course of action. The algorithm is defined as an organizational means of reaching a solution usually provided by a specific intervention from above.

The inherent goals of the second layer activity, the learning and adaptation level, is to reduce uncertainty. Given a set of priorities and goals and the importance of actions from a higher level, this learning or adaptation layer must decide how to respond to the needs prescribed from above. This layer must reduce the uncertainty in making responses and initiatives as much as possible providing a simplified job for the selection level.

The self-organizing layer must select and structure functions and strategies which should be used on the lower layers so that an overall goal or set of national interest can be pursued as closely as possible. It can change the directives for action to the first level if the overall

goal is not accomplished, or it can change the learning strategy used on the second layer if the estimation of uncertainties turns out to be unsatisfactory.

We can formalize the coordination of activities at this point. Consider the process P; it has two inputs: a control or intervention input from the second level (m from a given set M) and an input ω from a given set Ω , called the input. It also has an output y in a given set Y. The process P is assumed to be a mapping

$$P : M \times \Omega \rightarrow Y.$$

Looked at in foreign policy terms the process or selection level concerns the working out of daily actions in each of the bureaucracies involved in foreign policy. The tasks here are to apply an algorithm for responding to stimulae from the environment which has been provided by the second level. While it is true that some policy is "made in the cables" these changes in the algorithm for responding must be in harmony with the general outlines of objectives passed down from above or there is likely to be requests for a change in activity.

Next consider the second level in our control system. It has two inputs: coordination γ provided by the higher level from a given set Γ , and the feedback β from a given set ξ coming from the process. The output is the control intervention m selected from the set M_i. The system is a mapping

$$C_i : \Gamma \times \xi_i \rightarrow M_i$$

At the managerial level the task of coordinating the organizing goals of the Administration with the realities of the daily routine must be carried out. It is here that decisions about the feasibility of particular plans is decided. These levels must provide policy plans for

operators to use as algorithms in acting. It is the general case that this level must suggest plans, get them accepted by the Administration and implement them at this selection level.

The highest level is charged with the responsibility of coordination. It has only one set of inputs, namely the feedback information w from the second levels which it uses to arrive at the coordination output Y. The system is assumed to be a mapping

$$C_0 : W \rightarrow \Gamma ,$$

where W is the set of feedback inputs w. Except in rare instances, such as a crisis, the Administration sets national interest, chooses a policy plan or combines and suggests several plans from the managerial level and assigns responsibility to a lead Bureau at the second level, but it does not involve itself in the process directly.

To complete the description of this system we must specify the nature of the feedback information. The feedback information Z to the second level contains direct information on the process P; it is therefore a function of the control m, the disturbance ω and the output y, given by the mapping

$$f_i : M \times \Omega \times Y \rightarrow \xi i .$$

Similarly the feedback information w received by the highest level contains information concerning the behavior of the second level and therefore assumed to be given by a mapping

$$f_0 : \Gamma \times \xi \times M \rightarrow W ,$$

which is a function of the coordination Y, feedback $\underline{Z}$ and output m.

It should be pointed out that this functional hierarchy is based on the conceptual recognition of the essential functions in a complex

decision system. It provides only a starting point for a rational approach to assign proper functions to different layers. In fact, each functional layer can be implemented by further decomposition. For our purposes it is only essential to lay out the elements of the decision-making process and to borrow this functional hierarchy of levels or tasks so that we can demonstrate at what place a specific form of forecasting might be beneficially used. In order to do this, we need to make a set of assertions about the types of planning that each of these levels in a hierarchy must normally concern.

In spite of several common features the tasks and roles of the systems can be delineated by levels at this point

(1) A higher level unit is concerned with the larger portion or broader aspects of the overall foreign policy behavior. In hierarchical systems terms this is reflected in the fact that a higher level unit is superior to two or more units and the decision of the higher level coordinates the lower levels in accordance with the goal or objective defined over the domains of all the units subordinate to it.

(2) The decision period of a higher unit is longer than that of lower units. Simply put, the lower level units are responsible for today's decisions, whether to respond to previous actions or to initiate new actions. The time frame of these decisions are quite limited. However, to evaluate the effect of coordination, higher levels cannot act more often than the lower levels, whose behavior is conditioned by this coordination. Therefore, it is

essential to recognize inherent differences of the time frames in most decisions as we proceed up the decision hierarchy. Certainly there are specific strategies or issues such as the Cuban Missile crisis when the normal process is short-circuited by making most decisions operative at a much higher level in the hierarchy.

(3) A higher level unit is concerned with the slower aspects of the overall system's behavior. The lower levels of this decision tree are concerned with more particular local changes in the foreign policy process. The higher levels cannot respond to variations either in the environment or in the process itself which are faster than the variations of concern to the lower levels.

(4) Descriptions and problems of higher levels are less structured with more uncertainties and more difficult to formalize quantitatively. Decision problems in the higher levels can be considered as more complex and an approximation can be used to derive a solution to a higher level problem, but accuracy is then reduced. One has to be cautious when interpreting the results (Mesarovic (1970) pp. 54-55).

In general, for any level there is a specific set of techniques suitable for the solution of respective problems. As we have laid out the system characteristics, units of the higher echelons are concerned with broader aspects of the foreign policy task and therefore have a more complex decision problem than those on the lower levels. They have a

longer time frame with which to look at problems, and therefore are concerned with slower aspects of the overall foreign policy behavior. Among the most immediate potential benefits of applying this approach in research, the following are worth mentioning:

(1) It provides a unified basis for different approaches through a framework in which the various approaches can be compared, contrasted, and used to complement each other.

(2) It offers mathematical precision in defining both concepts and issues.

(3) It provides a starting point for mathematical and computer simulation studies of various issues and problems both in analysis and design of decision-making systems.

The approach being based on mathematical methods is primarily concerned with structural considerations such as communication, control, command, coordination, etc. However, it should be emphasized that the basic building block, a decision-making unit, is adaptable to multiple uses in foreign policy and event interaction analysis.

<u>The Explanation of National Behavior by Resort to National Attributes</u>

This area is perhaps the most well developed areas for theoretical explanation in international relations. Several authors have developed theories which attempt to explain behavior between nations. In their empirical definitions of behavior some have resorted to the events data. The primary use of events data in these approaches is to aggregate behaviors between nations over the time span of a year. There are several major approaches in this area and they can be briefly summarized. No extensive discussion of individual approaches will be attempted here, however, since this work is well cited in existing literature.

R.J. Rummel has attempted to link the international behavior of nations to differences and similarities in national attributes between nations. Rummel's field theory asserts that nations interact in a social field. This field is analytically divided into two spaces: a behavior space and a space of attributes. The field is a system defined by analytical coordinates and by the properties, relations and movements of the entities along the coordinates. The concept of field assumes that the characteristics of the field and the entities within it reciprocally influence one another.[17] Description of the field, therefore provides a basis for explaining the past, and in a measure, predicting the future (Wright (1955) p. 524). Conceptualizing international relations behavior as being located in a field begins with assumptions about time and space within which nations exist and events occur.[18] Geometry and linear algebra are the language for rewriting natural views of the world as a field. This conception has an intellectual heritage in the physical sciences but it has also found support in the social sciences (Lewin (1964), Wright (1965) and Bentley, (1954)).

For Rummel, nations are located within the attribute space in terms of their characteristics, such as economic; within the behavior space, dyads (such as USA-USSR) are located in terms of their behaviors such as trade. Then national attributes' similarities, and differences are field forces treating social time--space--motion; attribute distances between nations cause international behavior. Thus, for field theory, a social concept attribute distance--is a basic force (Rummel (1971), p. 5).

Leaving mathematical considerations aside, Rummel's field theory says simply that nations will behave toward each other in terms of their social, economic, geographic and political differences or similarities.

Test of the theory has so far been encouraging. In particular one analysis of the linkage of behavior between nations to their differences shows different levels of economic development to be a specifically important force in influencing the direction of behavior (Rummel, 1969).

Rummel is moving in the direction of increasing the number of axioms in such a way as to explain in more detail the relationship between behavior and attribute distances. This work relies heavily on the sociological concepts of rank and status previously used to explain international relations by Galtung (1966 a & b).

In contrast to Rummel's belief that it is the relative differences and similarities between nations which explain international relations, other analysts stress that the external behavior of society stems primarily from the effort to satisfy needs and wants. Thus the value structure and coherence of society are viewed as crucial to its external behavior irrespective of similarities or differences between the nation and other nations, hostile alliances forming or trade wars brewing. Nils Petter Gleditsch has suggested that we group all those who take this position under the title, Attribute Theorists (Gleditsch, 1970). Rosenau has suggested that three attributes of national societies--their size, their economic development, and their political accountability--are so basic to their way of life as to lead to fundamental differences in their foreign policy (1966, p. 27-92).

The eight types of societies that result from a dichotomization of the three national attributes are considered to be so different from each other that the impact of individual, governmental, societal and systemic variables would not be so great as to confuse distinctions in

behavior for each of the eight geno-types.[19] Propositions deriving from this taxonomy have been tested (Hermann and Salmore (1971), Rosenau and Hoggard (1971), Rummel (1968), Hermann (1972)). The results so far have been checkered indeed. It appears that cooperative behavior, trade, aid, and participation in the international system can be understood from knowledge of the attributes of an individual nation (Rummel, 1972). On the other hand, conflict behavior seems to be more complex than this theory would expect.

The common belief that internal strain on political instability within a state is related to its foreign conflict behavior has been seriously questioned by empirical analyses (Rummel (1963, 1966, 1968), Tanter (1966), Haas (1965)). Wilkenfeld had demonstrated that when one breaks down nations into groups based upon bureaucratic decision style, certain groups show a strong relation between domestic conflict and foreign conflict (Wilkenfeld, 1968 1969). Zinnes and Wilkenfeld (1969) have developed a model which attempts to account for the relationship internal political instability and foreign conflict activity. This model has been extended by Gillespie, Zinnes, and Wilkenfeld (1969). Another interesting attempt to demonstrate that there is a relationship between domestic unrest and foreign conflict behavior but that it is not a simple mapping of domestic unrest onto foreign conflict has been developed by Leo Hazelwood (1973).

Others feel that a particular type of social structure or regime has an impact upon the making of foreign policy. Whether a political system is open or closed, stable or unstable, assertions about the highest leaders of such systems and the impact on the decision-making of these leaders is currently being investigated. The Salmore's hypothesized

that the regime type has an important influence upon the foreign policy behaviors of the government (1972). Phillips and Hall (1969) demonstrated classification of nations according to bureaucratic characteristics does have an ability to distinguish between other characteristics of the nations lending credence to the possibility that difference of regime types have an impact upon foreign policy behavior.

The idiosyncratic characteristics of several decision makers is being investigated by Peg Hermann in an attempt to explain foreign policy behavior. It is her premise that the higher in the hierarchy of foreign policy organizations an individual's role is, the more likely are his personality characteristics to effect foreign policy decision. She feels that the most relevant personality variables to foreign policy making are the influences on the way the leader or head of state process information (1972).

The set of approaches to the explanation of international relations, based upon the attribute characteristics or the relations between the attributes of two or more nations is progressing quite well from an empirical standpoint. These authors have frequently relied upon event data to test their propositions. In their use of events data they have aggregated individual recordings of actions to yearly totals. Aggregation tends to cumulate the systematic components of data and cancel the random ones,[20] however, aggregation may increase the difficulty of choosing between alternative theories.[21] More importantly, while the data that is being used in testing these field and attribute theories relies in part upon events data as a source of empirical observation, the process of aggregating this data rejects the basic assumptions of the event movement.

We began this paper by a simple delineation of the assumptions implicit in those who prefer to collect what is termed event interaction data. They are, in slightly enlarged form:(1) What must be explained are the individual actions of nations states. (2) Behavior reflects purpose or intention. (3) Action is chosen as a calculated solution to a strategic problem. (4) Explicit statements and tactical moves of nations constitute strategic signals. Adversaries watch and interpret each others behavior, each aware that his own actions are being interpreted and each acting with the consciousness of the expectations which he creates. (5) Actions chosen are in response to strategic problems the nation faces. Threats and opportunities arising in the international strategic market place move the nation to act.[22] If these are agreed upon as the basic premises of those who choose to collect events data, aggregations of that data into yearly form provides measures of the total amount of exchange between nations in the same way that trade data, aid data, or any other transaction data would provide. That event analysts wish to consider their data different than transactions can be seen in the way they organize and record the information on an act by act basis.[23]

It can be argued that foreign policy decision systems such as those envisioned in the hierarchical systems model or the learning models are really recursive. It is difficult, for instance, to find examples of decisions where policy input and output are simultaneously determined. More realistically one must usually specify some sort of adjustment process at work. A nation sets the stage by making an act, another nation reacts. Interaction may be accumulated or ignored, third nations react to these nations or not, the activity becomes important enough to move

up the hierarchy of decision-makers or not. A crucial factor, however, is the time period involved. If the unit of time implied in the substantive model is each event, but the data is aggregated for periods larger than the substantive unity, then identification of the true explanatory variables is not possible. The aggregated year or monthly data is an approximation, but Johnson (1972) has shown that without further variables the model would not now even be unidentified. Even if identifying variables were present, enforced aggregation over time periods turns a truly recursive model to a fully simultaneous one with all the resultant estimation problems (1972, Chapter 13).

The impact of such an argument is that while the data is being appropriately employed in attribute analyses which aggregate at the monthly or yearly level, the model which underlies the data collection efforts of the event field is not being tested by attribute or field theories. Rummel has argued that without knowing the theory which underlies the collection of data it is inappropriate to discuss the implications of a particular data collection.[24] He is clearly not arguing that he would not accept events data to test his theory. On the other hand, the emphasis on the events data collection has confused the distinction between those who have developed a rationalization for collecting the data and those who have been most visible in employing the data to test their theories.

Thus international events data are no more than measures of some forms of international interactions. They are, or should be, simply indicators of substantive concepts bounded within theoretical frameworks. Trade, mail flows, hours of cross national radio broadcasts, and the number of tourists are legitimate measures of international

exchanges as are events. Previous preoccupation with events data *per se* has tended to confuse this issue. When actions are considered discrete signals of a national decision making bureaucracy, as most events data collectors argue, then systems models as developed in this paper are applicable. When events are aggregated and considered as indicators of the linkage between nations or as means of characterizing the foreign policy output of a nation, as the field and attribute theories view them, then the analysis employed by followers of those paradigms is correct. On the other hand, we cannot mix the systems paradigm with the aggregate analysis of the attribute/field theorists as this results in an inability to distinguish between differing systems theories.

Conclusion

This paper has attempted to identify the basic underlying assumptions accepted by those who collect events interaction data. While no single theory has been accepted by this group of data collectors, enough evidence seems available that it is possible to characterize the field. It is interested in the dynamics of foreign policy process. Emphasis is placed upon the development of algorithms for matching inputs and outputs. Simple linear models characterized as tit for tat models were reviewed and identified in the literature. Dynamic extensions of this approach to cover adaptation and learning were demonstrated and recommended. Use of events data by other theorititians was briefly reviewed. The conclusions of this review were that while event data was appropriate for testing these field and attribute theories, the assumptions which underlie the collection of events data are not being tested when the data is employed

in the field or attribute theories since the time frame of the aggregation is monthly or yearly.

The implications of the review are that a good deal more work needs to be pursued in the area of theoretical explanations for the normal relations between nations. The process of foreign policy making is not yet the subject of formal theoretical explanation while the substantive interests of events data collectors seems well developed explanations of the process delineated in the data have not reached maturity.

FOOTNOTES

1. The adjective was suggested by Rogowski (1968) and it is meant to comprehend both general systems theory and its derivatives or cognates as these have been applied to the study of international politics.

2. For propositions similar to the three assumptions stated here see McClelland (1961), Hermann (1972), Allison (1970).

3. For a solution to this problem see Phillips (1969).

4. It is important to keep in mind that this finding does not mean there will be no variation in a nation's or dyad's scores over time. Rather the dimensions along which nation's or dyad's behavior varies remain stable, i.e. the same, irregardless of the time slice used.

5. For a review of classification attempts in international relations see Sumner (1971).

6. For empirical proof of this point see Hilton (1971).

7. It is most distressing today that events data analysts must worry over the presentation of any paper. On the one hand, if their paper is an investigation into reliability or validity of their data they are attacked for being atheoretical. On the other hand, if they propose theoretical explanations to international phenomena they are attacked for not giving enough concern to the empirical questions. It is unfortunately the case that most statistical analyses precede - without appropriate theory and most theoretical activities are being criticized for the wrong reasons.

8. "The nations affect the actions of one another less by physically compelling changes in behavior than by acting on one another's perceptions and expectations: Interaction among nations is primarily a matter of threats, promises, and warnings designed to influence behavior by persuasion. Accordingly the primary vehicle for the exercise of international influence takes the form of "signals" among international actors. Actions - the outputs of the national security bureaucracy - are the "signals," designed to persuade another nation to alter its behavior in the preferred direction." (Halperin and Kanter, 1973, p. 60).

9. The term was originally suggested by Rapoport (1960).

10. Aron has raised the question as follows: "Is the cold war a preparation or substitute for total war?" If the former, the two camps are simply maneuvering for position until the day of final settlement. If the latter, the propaganda battles become the struggles among national parties, dividing localized in Greece and Korea, constitute the war itself--inevitably because of the ravages of violence (1954, p. 226).

11. The reader interested in pursuing mathematical learning theory might consult Atkinson, Bower, and Crothers (1965); Bush and Mosteller (1955); or Coombs, Dawes and Tversky (1970).

12. For procedures used in identifying specific values for alpha and beta see Bush and Mosteller (1955) or Rainio (1968).

13. These revisions were suggested by Yong-Ok Park.

14. This position is well developed in Ackoff and Emery (1972). Chapter 13.

15. For an introduction see Mesarovic, Macko, and Tackahara. (1970).

16. This development follows that of Mesarovic, et al.

17. Field theory assume, first, that international behavior and attributes form a social space - a field of complex and changing inter-relationships between nations, their characteristics, and their behavior. Isolating a particular variable or two is not sufficient to understand behavior, then. Rather, the whole field must be specified to provide the context and causal environment of interactions. For example, knowledge that a country with a left democratic government is poor and a Catholic will not generally be sufficient to explain a nation's international behavior. These characteristics have different behavioral consequences depending on their distribution in the system, behavioral expectations and norms, and on who is the behavioral object (Rummel, (1971), p. 4).

18. ". . . absolute characteristics are assumed outside of a nation's behaviorally relevant field and it is assumed that the principle of relative values governs nations: attributes and behavior must be understood by their interrelations, comparatively. Behavior cannot be explained in isolation and a nation's attributes become relevant only in relation to other attributes and to behavior.

". . . social time is assumed to be part of the international relations social space - the field. Nation behavior and attributes have extensional and durational relationships; the passage of time is relative to the nations and the context" (Rummel (1971), p. 4-5).

19. See Kendall (1950).

20. See Yule, Orcutt, Watts and Edwards (1968).

21. I have enlarged upon the original set of three assumptions so as to make clear the act by act characterization of these assumptions.

22. All code sheets that I am aware of are specific to an individual act.

23. Public discussion at International Studies Association meetings in Dallas, 1972.

BIBLIOGRAPHY

Ackoff, Russell L. and Fred E. Emery (1972) On Purposeful Systems. Chicago: Aldine.

Allison, Graham (1971) The Essence of Decision: Explaining the Cuban Missile Crisis. Boston: Little, Brown.

Aron, Raymond (1954) The Century of Total War. Garden City, N.Y.: Doubleday and Co.

Ashby, W. Ross (1969) Introduction to Cybernetics. New York: Barnes and Noble.

Atkinson, R.C., Bower, G.H. and Crothers, E.J. (1965) An Introduction to Mathematical Learning Theory. New York: Wiley.

Azar, Edward A. (1970b) "Profiling and Predicting Patterns of Inter-Nation Interactions: A Signal Accounting Model." Paper presented at the American Political Science Association Annual Meeting, Los Angeles, California, September.

________ (1971a) "The Conflict Escalation-Reduction Cycle: A Statistical Assessment of Internation Shifts." University of North Carolina, Studies of Conflict and Peace Report No. 2, November 1.

Baughman, Henry (1872) Dissertations: Historical and Political.

Bartos, Otomar (1966) "Concession-Making in Experimental Negotiations." in Joseph Berger, Morris Zelditch, Jr., and Bo Anderson (eds.). Sociological Theories in Progress. New York: Houghton Mifflin.

Bentley, Arthur F. (1954) "Inquiry into Inquiries" in Sidney Butner (ed.). Essays in Sociological Theory. Boston: Beacon Press.

Brunner, Ronald P. (1970) "Data Analysis, Process Analysis and System Change." Paper prepared for the 66th Annual Meeting of APSA.

________ and Gary D. Brewer (1970) "Policy and the Study of the Future: Some Reflections on Method." Paper presented at the Annual Meeting of the International Studies Association, Pittsburgh.

Burrowes, Robert (1969) "Conflict and Cooperation Within and Between Nations: Israel, the United Arab Republic and the Major Arab States of Southwest Asia, 1949-1969." Paper presented at the Annual Meeting of the American Political Science Association, New York City, September.

________ (1970a) "Multiple Time-Series Analysis of Nation-Level Data." Comparative Political Studies. XI (January): 465-490.

________ (1970b) "Conflict and Cooperation Within and Among Nations: Enumerative Profiles of Syria, Jordan and the United Arab Republic, January 1965 to May 1967." Paper presented at the Annual Meeting of the International Studies Association, Pittsburgh, April.

________ and Jose Garriga, Jose Mussio and Bert Spector (1970) "The Road to the Six Day War: A Relational Analysis of Conflict and Cooperation Within and Between the Arab-Israeli and Inter-Arab Political Domains." Paper presented at the Annual Meeting of the Middle East Studies Association, Ohio State University, Columbus, Ohio, September.

________ and Bert Spector (1969) "The Strength and Direction of Relationships Between Domestic and External Conflict and Cooperation: Syria, 1961-1967." Paper presented at the Annual Meeting of the American Political Science Association, New York City, September.

Burton, John (1968) Conflict and Communication. New York: The Free Press.

________ (1969) Systems, States, Diplomacy and Rules. Cambridge: Cambridge University Press.

Bush, Robert and Fredrick Mosteller (1950) Stochastic Models for Learning. New York: John Wiley and Sons.

Cain, G. and H. Watts (1970) "Problems in Making Policy Inference from the Coleman Report." American Sociological Review. (April) pp. 228-252.

Cherry, Colin (1957) On Human Communications. Cambridge: MIT Press.

Coombs, C. H., R. M. Dawes and A. Tversky (1970) Mathematical Psychology Englewood Cliffs, Prentice Hall.

Corson, Walter (1970a) "Conflict and Cooperation in East-West Crisis: Measurement and Prediction." Paper presented at the Michigan State University International Events Data Conference, East Lansing, April.

Denton, Frank H. and Warren R. Phillips (1968) "Some Patterns in the History of Violence." Journal of Conflict Resolution, XII (June) pp. 182-195.

Deutsch, Karl (1968) The Analysis of International Relations. Englewood Cliffs: Prentice Hall.

Driver, Michael J. (1968) "Crisis and Reciprocity in Soviet American Interactions: A Newspaper Headline Analysis." University of Southern California, August.

East, Maurice and Charles F. Hermann (1972) "Do Nation-Types Affect Foreign Policy Behavior?" Paper presented for Annual Meeting of the American Political Science Meeting, Washington, D. C., September 5-9.

Forsyth, M. G., et.al. (1970) The Theory of International Relations. New York: Atherton.

Galtung, Johan (1966a) "International Relations and International Conflicts: A Sociological Approach." Transactions of the Sixth World Conference of Sociology, Evian.

______ (1966b) "Rank and Social Integration: A Multidimensional Approach." In Berger, Zelditch and Anderson (eds.) Sociological Theories in Progress. New York: Houghton Mifflin.

Gentili (1598) On the Law of War.

Gentz, Fredrick Von (1806) Fragments Upon the Present State of the Political Balance of Europe.

Gillespie, John, Dina Zinnes and Jonathen Wilkenfeld (1969) "Consistency and Inconsistency of Foreign Policy." Paper prepared for the annual meeting of the American Political Science Association, New York.

Gleditsch, Nils Petter (1970) "Rank Theory, Field Theory, Attribute Theory: Three Approaches to Interaction in the International System." Honolulu: University of Hawaii. DON Project Research Report # 47.

Haas, Michael (1965) "Societal Approaches to the Study of War." Journal of Peace Research, pp. 308-323.

Hall, Dennis and Rudolph J. Rummel (1968a) "The Dynamics of Dyadic Foreign Conflict Behavior: 1955 to 1963." Dimensionality of Nations Project Research Report, University of Hawaii.

______ and ______ (1968b) "The Patterns of Dyadic Foreign Conflict Behavior for 1963." DON Report no. 12, University of Hawaii, June.

Halperin, Morton H. (1970) Bureaucratic Politics and Foreign Policy. Washington: The Brookings Institution.

______ and Arnold Kantar (1973) Readings in American Foreign Policy. Boston: Little, Brown.

Hazelwood, Leo (1973) "Externalizing Systematic Stress: International Conflict as Adaptive Behavior." In Wilkenfeld (ed.) Conflict Behavior and Linkage Politics. New York: McKay.

Hermann, Charles F. (1970b) "What is a Foreign Policy Event?" Paper presented at the Michigan State University International Events Data Conference. East Lansing, April.

______ (1972) "Policy Classification: A Key to the Comparative Study of Foreign Policy." In Rosenau, Davis and East, The Analysis of International Politics. New York: The Free Press.

______ and Stephen Salmore (1971) "The Recipients of Foreign Policy Events." The Ohio State University.

Hermann, Margaret G. (1972) "How Leaders Process Information and the Effects on Foreign Policy." Paper prepared for Annual Meeting of the American Political Science Association, Washington, D. C., September 5-9.

Hill, Gary A. (1971) "The Flow of International Events." WEIS Project Technical Report, January.

Hilsman, Roger (1971) The Politics of Policy Making in Defense and Foreign Affairs. New York: Harper and Row.

Hilton, Gordon (1972) Causal Inference Analysis: A Seductive Process. Printed in Administrative Science Quarterly, pp. 44-57.

Hoffman, Stanley (1968) Gulliver's Troubles or the Setting of American Foreign Policy. New York: McGraw-Hill.

Holsti, Ole R. (1965) "Perceptions of Time, Perceptions of Alternatives and Patterns of Communication as Factors in Crisis Decision-Making." American Political Science Review, LIX.

______, Richard A. Brody and Robert C. North (1964) "Measuring Affect and Action in International Reaction Models: Empirical Materials from the 1962 Cuban Crisis." Journal of Peace Research. I, pp. 170-189.

______, Robert C. North and Richard Brody (1968) "Perception and Action in the 1914 Crisis." In J. David Singer (ed.) Quantitative International Politics: Insights and Evidence. New York: The Free Press.

Johnston, J. (1972) Econometric Methods. New York: McGraw-Hill.

Kaplan, Morton (1957) System and Process International Politics. New York: John Wiley and Sons, Inc.

Langer, William L. (1931) European Alliance and Alignments. New York: Knopf.

Levy, Marion J. (1969) "Does it Matter if He's Naked Bawled the Child." In Knorr and Rosenau (ed.) Contending Approaches to International Politics. Princeton: Princeton University Press.

Lewin, Kurt (1964) Field Theory in Social Science. D. Cartwright, (ed.) New York: Harper Torchbooks.

McClelland, Charles A. (1961) "The Acute International Crisis." World Politics. 14 (October): 182-204.

_________ (1964) "Action Structures and Communication in Two International Crises: Quemoy and Berlin." Background, VII (February): 201-215.

_________ (1966) Theory and the International System. New York: MacMillan.

_________ (1968a) "Access to Berlin: The Quantity and Variety of Events, 1948-1963." In J. David Singer (ed.) Quantitative International Politics: Insights and Evidence, pp. 159-186. New York: The Free Press.

_________ (1973) "The Beginning, Duration, and Abatement of International Crises: Comparisons in Two Conflict Arenas." In Charles F. Hermann (ed.) International Crises.

_________ and Anne Ancoli (1970) "An Interaction Survey of The Middle East." University of Southern California, March.

_________, Daniel P. Harrison, Wayne R. Martin, Warren R. Phillips and Robert A. Young (1965) The Communist Chinese Performance in Crisis and Non-Crisis: Quantitative Studies of the Taiwan Straits Confrontation, 1950-1964. China Lake, California: U.S. Naval Ordinance Test Station, NOTS TP 4138, May.

_________ and Gary Hoggard (1969) "Conflict Patterns in the Interactions Among Nations." In J. Rosenau (ed.) International Politics and Foreign Policy, pp. 711-724. New York: The Free Press.

_________, Rodney G. Tomlinson, Robert G. Sherwin, Gary A. Hill, Herbert L. Calhoun, Peter H. Fenn, and J. David Martin (1971) The Management and Analysis of International Event Data, September.

_________ and Robert A. Young (1969) "Some Preliminary Short-Term Predictions of International Interaction." World Event/Interaction Survey Working Paper #1. University of Southern California, September.

McGowan, Patrick (1970) "A Formal Theory of Foreign Policy Behavior as Adaptive Behavior." Paper delivered at The 66th Meetings of the APSA.

Mesarovic, M. D. et.al. (1971) Theory of Hairarchial Multilevel Systems. New York: Academic Press.

Morse, Edward (1970) "The Transformation of Foreign Policy." World Politics. Vol. 53, pp. 371-392.

North, Robert C., Richard A. Brody and Ola Holsti (1964) "Some Empirical Data on the Conflict Spiral." Peace Research Society Papers, I: 1-14.

Oliva, Gary and Rudolph J. Rummel (1969) "Foreign Conflict Patterns and Types for 1963. "Dimensionality of Nations Project Research Report No. 22. University of Hawaii, April.

Orcutt, Guy H., Harold W. Watts, and John B. Edwards (1968) "Data Aggregation and Information Loss." American Economic Review. Vol. 68. (September) pp. 773-787.

Phillips, Warren R. (1969) Dynamic Patterns of International Conflict. Ph.D. Dissertation and Dimensionality of Nations Project Research Report No. 33. University of Hawaii.

_________ (1970a) "A Mathematical Theory of Conflict Dynamics." Dimensionality of Nations Project Research Report No. 39. University of Hawaii.

_________ (1971) "The Dynamics of Behavioral Action and Reaction in International Conflict." Papers of the Peace Research Society.

_________ (1973) "The Conflict Environment of Nations: A Study of Conflict Inputs to Nations in 1963" in J. Wilkenfeld (ed.) Conflict Behavior and Linkage Politics. New York: McKay.

_________, and Robert C. Crain (1972) "Dynamic Foreign Policy Interactions: Reciprocity and Uncertainty in Foreign Policy." To be published in the International Yearbook of Foreign Policy Studies (1974). Los Angeles: Sage Publications, Inc.

_________, and Michael Hainline (1972) "Crises Typologies." The Ohio State University (mimeo).

_________, and Michael Hainline (1973) "Major Power Conflict Exchanges in the Sixties: A Triadic Analysis of the Soviet, U.S. and Chinese Subsystems." Behavioral Sciences Laboratory Mimeo.

_________, and Theron Lorimore (1972) "The Effect of Crises Upon The Stability of International System." The Ohio State University. (mimeo).

Pruitt, Dean (1969) "Stability and Sudden Change in Interpersonal and International Affairs." in James N. Rosenau (ed.) International Politics and Foreign Policy: A Reader in Research and Theory. New York: Free Press.

Rainio, Kullervo (1966) "A Study of Sociometric Group Structure: An Application of a Stochastic Theory of Social Interaction" in Berger, Zelditch, and Swanson, Sociological Theories in Progress. New York: Houghton Mifflin.

Rapoport, Anatol (1960) Fights, Games and Debates. Ann Arbor: University of Michigan Press.

Richardson, Lewis F. (1960) Arms and Insecurity. Pittsburgh: Boxwood Press.

Rogowski, Ronald (1968) "International Politics: The Past as Science." International Studies Quarterly. Vol. 12 No. 4 (Dec).

Rosecrance, Richard (1964) Action and Reaction in World Politics. New York: Little Brown.

Rosenau, James N. and Gary D. Hoggard (1971) "Foreign Policy Behavior in Dyadic Relationships: Testing A Pre-Theoretical Extension." Paper Presented at Annual Meeting of International Studies Association, San Juan, March 17.

Rummel, Rudolph J. (1963) "Dimensions of Conflict Behavior Within and Between Nations." General Systems: Yearbook of the Society for General Systems Research, VIII: 1-50.

_________, (1964) "Testing Some Possible Predictors of Conflict Behavior Within and Between Nations." Peace Research Society Papers, pp. 79-111.

_________, (1965) "A Field Theory of Foreign Conflict Behavior." Peace Research Society: Papers IV, Cracow Conference.

_________, (1965) "A Field Theory of Social Action with Application to Conflict within Nations." General Systems: Yearbook of the Society for General Systems Research, X.

_________, (1966) "Dimensions of Conflict Behavior Within Nations." Journal of Conflict Resolution, X. March: pp. 65-73.

_________, (1969) "The Relationship Between National Attributes and Foreign Conflict Behavior," in David Singer (ed.) Quantitative International Politics: Insights and Evidence. New York: The MacMillan Press.

_________, (1970a) "U.S. Foreign Relations: Conflict, Cooperation and Attribute Distances." Dimensionality of Nations Project Research Report No. 41. University of Hawaii, July.

_________, (1970b) "New Developments in Field Theory: The 1963 Behavior Space of Nations." Paper presented at the Seventh European Peace Research Society (International) Conference. Rome, Italy. August.

_________, (1972) The Dimensionality of Nations. Los Angeles: Sage Publishing Co.

Salmore, Barbara and Stephen Salmore (1972) "Structure and Change in Regimes--Their Effect on Foreign Policy." Paper prepared for Annual Meeting of the American Political Science Association, Washington, D.C., September 5-9.

Shannon, Claude E. and Warren Weaver (1949) The Mathematical Theory of Communication. Urbana: University of Illinois Press.

Simon, Herbert A. (1958) Administrative Behavior. New York: MacMillan.

_________ (1969). The Sciences of the Artificial. Cambridge: MIT Press.

Smoker, Paul (1964) "Fear and the Arms Race: A Mathematical Study." Journal of Peace Research, Vol. 1, pp. 55-64.

_________ (1969) " A Time Series Analysis of Sino-Indian Relations." Journal of Conflict Resolution, XIII, (June), pp. 172-191.

Sorokin, Pitirim (1956) Fads and Foibles. Chicago: Henry Regency.

Sullivan, John D. (1964) "Quemoy and Matsu: A Systematic Analysis." San Francisco State College mimeo.

Swanson, Dean (1972) "The Construction and Use of Nation Typologies in I.R." Ohio State University mimeo.

Tanter, Raymond (1965) "Dimensions of Conflict Behavior Within Nations 1955-1960: Turmoil and Internal War." Peace Research Society Papers, III, pp. 147-156.

_________ (1966) "Dimensions of Conflict Behavior Within and Between Nations, 1958-1960." Journal of Conflict Resolution, X (March), pp. 41-64.

_________ (1972) "International System and Foreign Policy Approaches: Implications for Conflict Modeling and Management." World Politics. XXIV, pp. 7-39.

Vattel (1758) The Law of Nations.

Wilkenfeld, Jonathan (1968) "Domestic and Foreign Conflict Behavior of Nations." Journal of Peace Research. Vol. V No. 1, p. 56-69.

_________ (1969) "Some Further Findings Regarding the Domestic and Foreign Conflict Behavior of Nations." Journal of Peace Research. Vol. VI No. 2, pp. 147-156.

Wright, Quincy (1955) The Study of International Relations. New York: Appleton-Century-Crofts.

Young, Robert A. (1970) "An Events-Based Nation Typology." Consolidated Analysis Center, Inc. mimeo.

_________ (1970) "Prediction and Forecasting in International Relations: Some Theoretical Issues." WEIS Technical Report #5. University of Southern California.

Yule, G.V. and M.G. Kendall (1950) Introduction to the Theory of Statistics, London: Griffin.

Zinnes, Dina A. and Jonathan Wilkenfeld (1972) "An Analysis of Foreign Conflict Behavior of Nations," in W. Hanreider (ed.) Comparative Foreign Policy: Theoretical Essays. David McKay, Inc.

_______ (1968) "The Expression and Perception of Hostility in Prewar Crises: 1914," in J. David Singer (ed.). Quantitative International Politics. New York: The Free Press.

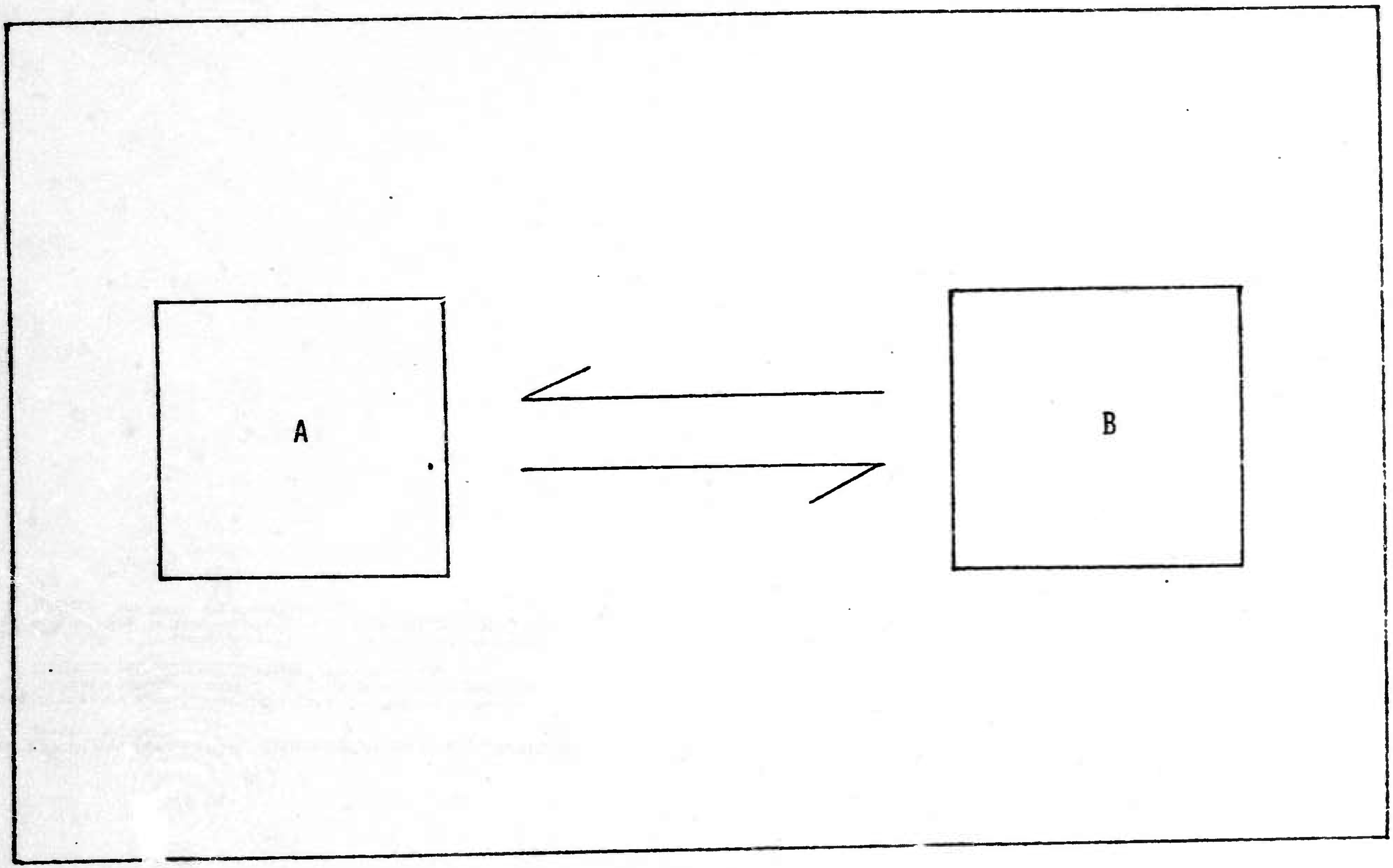


FIGURE I - BASIC PATTERN OF INTERACTION

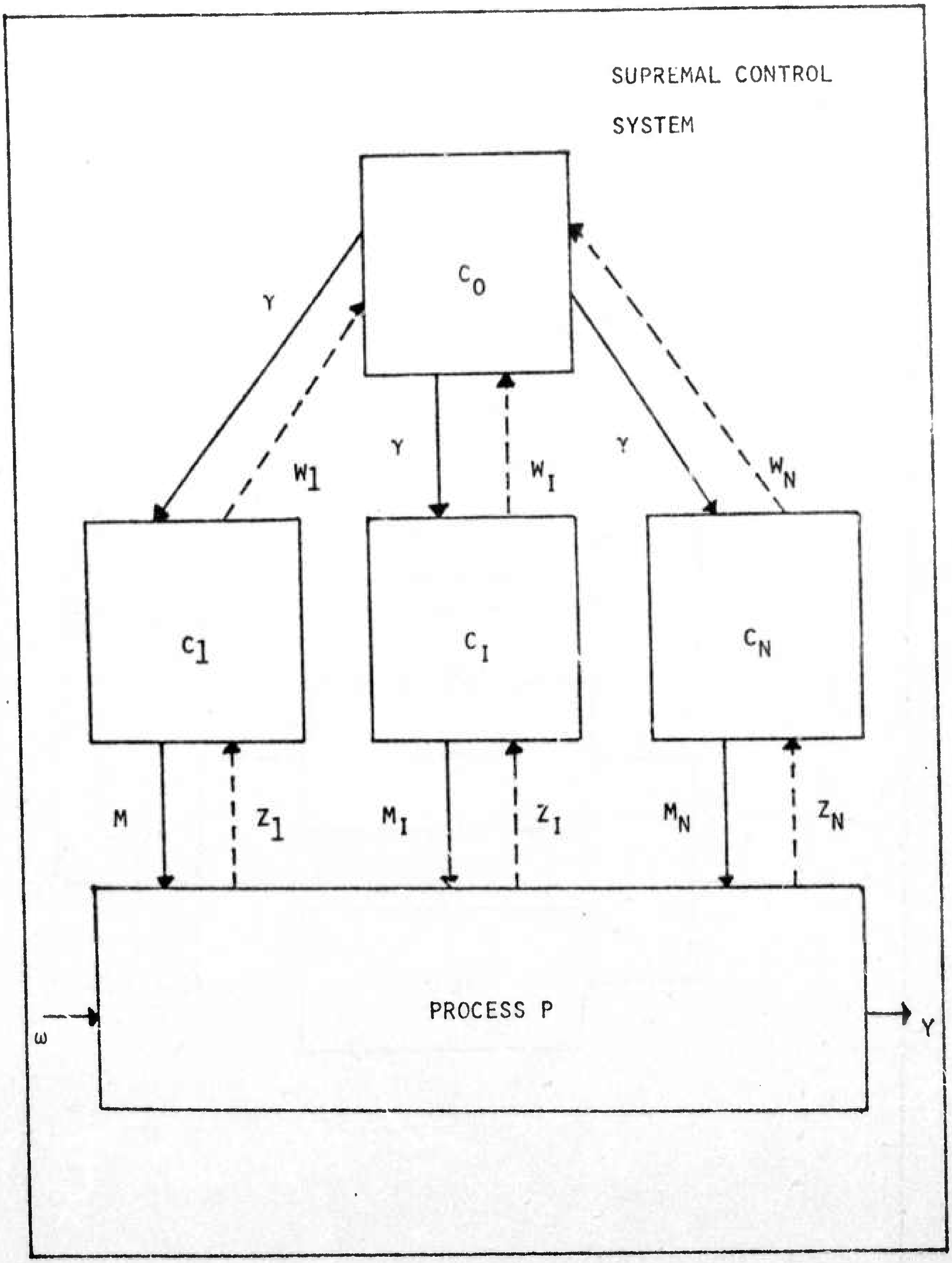


FIGURE II - A TWO-LEVEL SYSTEM WITH N INFIMAL CONTROL SYSTEMS AND A SINGLE SUPREMAL CONTROL SYSTEM*

*TAKEN FROM MESAROVIC, ET AL., 1971, P. 86.

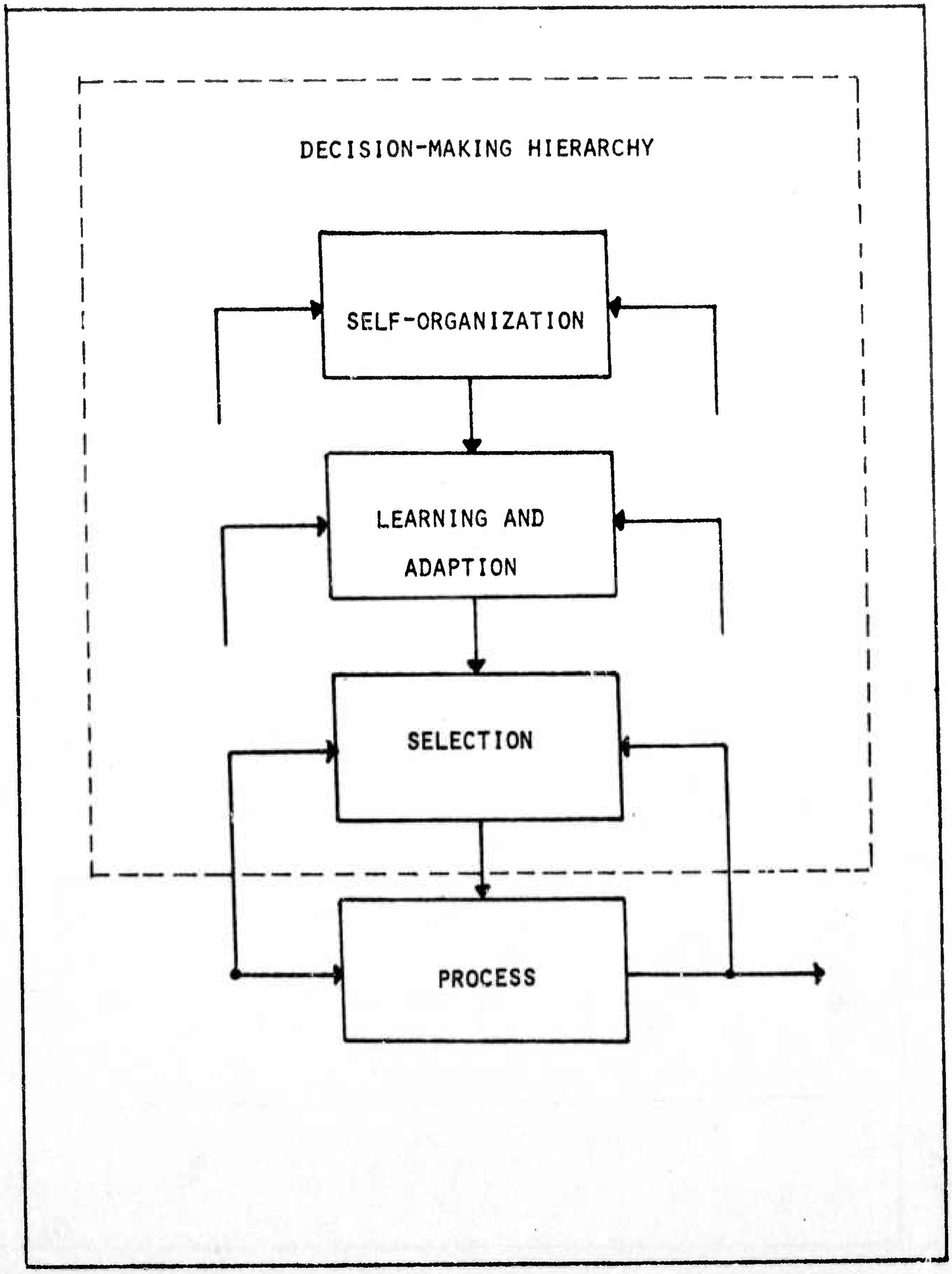


FIGURE III - FUNCTIONAL MULTILAYER DECISION HIERARCHY*

*TAKEN FROM MESAROVIC, ET AL., 1971, P. 47

Forecasting for Planning

Warren R. Phillips
Department of Political Science
The Ohio State University

March 1973
Project Research Paper No. 2

Paper prepared for delivery at the ISA Meetings in New York, March 13-17, 1973, to appear in Hilliker (ed.), Knowledge and Diplomacy: The Interaction of Research and Foreign Policy, forthcoming.

Prepared in connection with research supported by the Advanced Research Project Agency, ARPA Order No. 2345-3D20, Contract No. DAHC 15 73 C 0197, RF 3527-A1.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Project for Theoretical Politics The Ohio State University 053 Administration Building	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

"Forecasting For Planning"

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Research Report # 2

5. AUTHOR(S) (First name, middle initial, last name)

Warren R. Phillips

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 30, 1973	57	50

8a. CONTRACT OR GRANT NO. DAHC15 73 C 0197 b. PROJECT NO. A.O. 2345-3D20 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) # 2 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited and production in whole or in part is permitted for any purpose of the United States Government.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Advanced Research Projects Agency Washington, D.C.

13. ABSTRACT

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

Forecasting for Planning

By whatever name--forecasting, prediction, projection, estimation, or anticipation--this activity goes on constantly in the process of foreign policy decision making. Forecasting usually involves the use of images of how the environment, be it of nations, organizations, or individuals, operates to produce: estimates of probable occurrences, series of alternative futures, the impact of given actions, or the future direction of some process. In many instances the activity of forecasting is not explicitly stated, but it is fairly easy to infer from policy justifications. For instance the statement, "we must meet Communist agression wherever it occurs," has the implication that the Sino-Soviet Bloc is likely to attack other countries with military force in the future. Or the assertion, "if Israel's military capabilities decline, the Arabs will attack," is an expectation of the Arab state's decision process. An assertion of the nature, "our energy needs by the year 2000 will be difficult to acquire," is based on the assumption of the trends in our use of energy as well as trends in the supply of natural resources.

While forecasting ha[illegible] en allocated a discrete chapter in this book, it is tightly intertwined with goal setting, data collection, and model building. The government formalizes short range forecasting through the device of intelligence estimates (NIE's) which purport to define a range of probabilities within which policy making can operate with some assurance. The estimates proceed decisions about US actions in a particular issue or arena and are the coalition of data available and images of how a particular issue is likely to develop. The Inner Services Committee on Long Range Forecasting has as a principal goal the integration of forecasting for planning activities throughout the various services of the

Defense Department. Such documents as the Joint Chiefs of Staff's (JSOP, and JLRSS) are based upon formal and informal estimates of the future environment in which U. S. foreign policy is expected to be effective.

The policy process in which these plans become operational is dominated by negotiation and bargaining in which organizational as well as personal influence and power are often more persuasive than the substance of the policy problems. We can identify in this decision arena, several forms of policy planning which are admittedly subject to bureaucratic politics but are also representative of the types of planning which rely heavily upon forecasting.[1]

1. <u>Contingency Planning</u>: This first type of planning--contingency planning--is based upon scenarios of possible crises with which the United States is likely to be faced in the future. Preparing operational plans for these possible eventualities enables policy makers to analyze the effects which crises would have upon the current stability of international relations and speculate upon the most effective responses. While contingency planning is a useful exercise in that it enables policy planners to identify potentially harmful or dangerous situations and relevant actors who are likely to be involved, were these situations to come about, it is of limited usefulness because domestic political contexts in which decisions must be made to predict and also because the scenarios foreseen in the plans are seldom duplicated in real crises.

2. Program Planning: This form of planning occurs regularly in agencies like USIA, AID, Peace Corps, parts of the State Department and Defense Department which carry out programmatic activities and where planning can be accomplished without frequent and major interference by forces outside the United States control. Program Planning tends to idealize a non-political criterion--efficiency--as opposed to a political one--consensus. Its greatest potential seems to be recognized in the Defense budget cycle which involves a complicated series of programs and weapons systems all of which require the long run allocation of measurable resources. This form of planning attempts to institutionalize the process of foreign policy planning. Most of the detailed planning of this nature is under the exclusive control of the executive agencies. Congress does not seem to have the resources or facilities available to duplicate this effort at the current time.

3. Country Analysis and Strategy Planning: This form of planning is most actively pursued in the State Department from which the title actually comes.[2] It is the antecedent of PARA and is a planning document developed by the operators from country teams abroad to assist Assistant Secretarial levels and above in Washington. Country analysis and strategy papers identify U. S. goals and objectives in individual countries, project U. S. levels of concern and discuss courses of actions which American foreign policy should take to meet our goals in each specific country.

4. Issue Research: This is the final form of planning. It is less formalized than the country analysis and the strategy papers are more

directly relevant to specific policy problems facing U. S. decision-making. Most issue analysis is performed by policy officers as a potent vehicle of advocacy in an issue oriented department. It tends to be in response to requests from higher officials to produce a policy paper which will enter into the bargaining processes across governmental agencies in an attempt to predict future events associated with a specific issue such as likely positions of other nations at the CCD meetings and recommend specific U. S. action with regard to such an expectation.

The following examples and discussion of planning activities requiring forecasts point out that forecasting is predecision in nature. It is usually the case that expectations of how the system works and what the reactions of other nations are likely to be to U. S. initiatives become inputs to the decision process. They are taken into consideration in some decisions more seriously than others, and in some issues more formally than others before decisions are reached. In general it can be asserted that there is a lack of explicitness in the forecasting for planning.[3]

In order to make sense of the complex environment in which U. S. foreign policy is developed, planners use various tools to organize and order their experience. One of these tools is the model--a set of elements together with the relations defined upon them. A model may be of many types, e.g., physical, mathematical or mental. A mental model or image is simply an abstraction of various aspects of perceptual experience. For example a decision maker might have a mental model of how decisions are made in Brazil. He would then use this image in evaluating the potential impact of alternative U. S. policies toward

that country. These mental models or images are frequently relied upon. There are major problems associated with this form of modeling, however. For example, decision makers have many different mental images each dealing with a wide range of overlapping problems, and each, frequently, inconsistent with the others. Planners are faced with difficulties in knowing which images are applicable in a specific case. Since the relationships in each image are not explicitly and clearly identified, the sources of contradiction are not immediately obvious. Policies made upon the basis of such images of the world are likely to have unintended and often undesirable consequences.[4]

In addition, the lack of explicitness in mental images makes it difficult to communicate the assumptions upon which strategy preferences are based. In these cases disputes about policy alternative or outcomes may actually result from unidentified disagreements concerning the implications of actions. Perhaps more importantly from a long range planning perspective, it is difficult to manipulate the variables in mental images in order to assess the various impacts of U. S. actions. That is, the complexity of social phenomena makes it almost impossible to move from a vague set of assumptions about the world through the dynamic consequences these assumptions have for the impact of various policy alternatives.

Unfortunately, the obstacles to planning have been especially profound in foreign affairs. Neither the political process nor the foreign affairs bureaucracy has encouraged a serious consideration of long range problems. Moreover, the practitioner's firm convictions that international events are

inherently unpredictable has provided additional support for the belief that planning is doomed to failure: events cannot be foreseen and must be dealt with as they occur. But this argument is misleading for three reasons: point prediction is not a good criteria, the predictions may cause self correcting activity which prevents the expected occurrence, and forecasting of an intuitive nature goes on daily by those very people who would distain the effort. The last point has already been amply demonstrated.[5]

In the first issue, attempts to plan for the future may not require specific predictions of the occurrence of an event but may rely upon the forecasts of impact of a strategy upon the flow of events. In this case, the criteria of an accurate measure of the liekly impact of a particular choice among alternative strategies is more important than the prediction of specific events. In the second case, the forecast of future events fails to come true because it was made. These self defeating forecasts arise from rational acts on the part of people who make and believe the forecasts. As an example, predictions were made in the 1950's that the U. S. would be faced with a shortage of scientists and engineers. This prediction led to a change in the pattern of enrollments in graduate schools which obviously negated the prediction. The point to be made at this time is that predecision agreements over the validity of a forecast are not a good measure of its value. A more appropirate measure of value is its utility in helping the decision-maker make a correct and timely decision.

The concept of using a forecast as decision information has already been introduced. The cycle of activity of a foreign policy organization has been identified in earlier chapters and stages in this cycle performed the function of identifying chapter titles. The forecast serves as a predicion input to the process of making plans and decisions. As argued above the utility of a forecast

is measured by its potential roles in the planning and decision processes. Lenz has expressed the role of the forecast in planning as follows:

a. The forecast identifies limits beyond which it is not possible to go.

b. It established feasible rates of progress, so that the plan can be made to take full advantage of such rates. It does not demand an impossible rate of progress.

c. It describes alternatives which are open and can be chosen from.

d. It provides a reference standard for the plan. The plan can thus be compared with the forecast at any point in time, to determine whether it can still be fulfilled or whether, because of changes in the forecast, it has been changed.

e. It furnishes warning signals, which can alert the decision-maker that it will not be possible to continue present activities.

In performing each of these functions, the forecast provides specific pieces of information needed by decision-makers and planners.

Done well, planning could be of great practical significance. It would provide the criteria by which present choices can be worked through. Forecasting, the backbone of planning, is a primary area of potential cooperation between theorist and practitioners. Rothstein argues:

"This means that the failures of planning cannot be attributed solely to the imperfections of practitioners and the practical world. Some responsibility must fall on those social theorists who believe that any professional involvement with practical matters is intrinsically wrong and must be avoided. Since planning is an intellectual exercise--directed at very practical ends--which cannot be carried out in isolation from the analytical skills of the theoretical realm, the attempt to isolate theorists from practitioners dooms planning. The few practical men who

might be so inclined to plan lack the tools to do it well, and the few theoretical men who might be so inclined lack either the opportunity or the incentive." (1972, pp. 10-11)

The social sciences represent as yet a largely untapped resource with utility for planners in forecasting. An effort to bring the techniques and the substantive knowledge of the social sciences to bear on these problems should be worthwhile because:

1. The problems in planning and forecasting are so important that those charged with these tasks should draw upon a wide ranging set of intellectual resources, not only ranging widely across topics but delving deeply into critical problem areas which appear to be relevant.
2. The nature of scientific development is that it is cumulative, the knowledge gained in the past five years has added considerably more to the warehouse of knowledge than the ten years before that. In this respect, the previous five years has seen substantial support for basic research. It is now appropriate to use this information in applied, mission oriented projects.
3. The advances in the social sciences include not only substantive material but new methods and techniques, as well. These techniques include methods of forecasting outcomes of given actions or ranking a set of strategies against a list of desired outcomes in terms of effectiveness.
4. There is a growing interest on the part of policy oriented social scientists in practical problems. Their contributions can include analytical skills, basic research knowledge, experience with data retrieval systems, and the capability to assess current sources of information used by planners and forecasters. The interest of

this group of essentially problem solvers becoming involved, directly, with planners and forecasters provides a renewed hope for useful exchanges between scientists in the academic community and users.[6]

The development of an open dialogue between policy planners and social scientists on the roles and functions of forecasting should provide a series of gains to foreign policy decision-making.

1. More applicable scientific knowledge in the fields of planning and forecasting especially in the form of analytically assessing the impact of U. S. strategies with regard to a specific set of issues could be developed.[7]
2. More extensive experience in bringing policy users and academics together to work on practical problems should provide academics with more cognitive complexity in differentiating the world of public decision-makers, thereby insuring more specific assistance in the future. It should also give users an ability to use scholars more effectively in the future.[8]
3. The results of such an exchange should identify areas where more basic research is needed by policy planners. The weak points identified in such exchanges would become the rationale for further research which could be used as needed by forecasters.[9]

Having given away my prejudices in the early introduction of this chapter, it is now the task of showing how and where such scientific knowledge is applicable. Recent attention in theory and research on the bureaucratic handling of foreign policy questions has focused upon dealing with problems of knowledge usefulness in policy decision-making, transfers of knowledge to action, criticizing policy, and describing governmental behavior. Finding a mutually agreeable

approach to understanding the bureaucratic decision-making apparatus is difficult, however. Allison has underscored this problem: ". . . bureaucracy is the least understood source of unhappy outcomes produced by the U. S. government. Calls for the elimination of bureaucracy are, however, non solutions. Large organizations that function according to routines, and politics among individuals who share power, are inevitable features of the exercise of public authority in modern society." (1971, p. 266)

For our purposes a simple classification of the actors in foreign policy decision-making processes should suffice. Figure I presents a simple designation of the foreign policy decision-making actors. The essential characteristic of this process is that it is a multi-agency decision process. It is claimed that President Truman had a sign on his desk which read, "The Buck Stops Here." In our delineation of the multiple actors in foreign policy making, the President and his staff along with the National Security Council and the verification panels are the highest unit of decision-making.[10]

From his vantage point, the President has a unique perspective on foreign policy making. His responsibility is to view the total picture of both domestic and foreign affairs. The national political responsibilities at this level are most likely to be affected by personal idiosyncracies. The President's own style of politics and his personal style of decision-making affect in significant ways the roles that other players in this system are likely to perform. Under President Nixon's guidance it would appear that he prefers quite strongly to manage foreign affairs from this perspective. Kissinger's reluctance and refusal to bring Congress and the rest of the administration into the process reflects Nixon's desire to control the foreign policy from the White House. From this

perspective an overall rationality for the whole system must be developed. This rationality is neither associated with nor necessary for the other major levels in the policy-making process.

At the second level of actors, I have grouped together Stemple's senior political officers and managers in each of the five major foreign policy agencies: The Department of State, the Office of the Secretary to Defense, the Joint-Chiefs-of-Staffs, the Arms Control and Disarmament Agency, and the Central Intelligence Agency. The men in charge of these agencies manage sizable bureaucracies and their responsibilities to these specific institutions influence their goals and perspectives in quite different ways than goals developed at the higher level. The major impact and responsibility of these men is the coordination of the directives from National Security Council and the President with the information needs of the working level policy makers. Managerial level personnel actually control the work of the government in foreign affairs. They are the link between working bureaucracy and Presidential or senior political officers. Hillsman asserts:

> "Significant items of foreign policy cannot be managed at a lower level than a member of the administration, a man who is appointed by the President and who is therefore in a position at least to begin to inject into policy the broad political considerations . . ." (1971, p. 34)

Below this level are the working level policy makers. These personnel draft papers, clear them with other agencies, present them to higher levels, and control the amount and quality of information which is communicated up the hierarchy. Their information and organizational knowledge is considerably higher in technical questions of what is the host country doing today, or what is the current capability of the Israeli air force. They do not hold major

responsibility for questions of value. These questions are the main domain of the Presidential level and the senior political officers. This group includes desk officers in regional bureaus at the State Department, functional specialists and all office directors in all agencies. They probably have more leverage than an organizational chart of this nature would lead one to suspect, since they often control the information which is passed up the hierarchy.

John Stemple has summed up the essential aspects of this chart.

"Each of the four levels play a distinct role in the policy decision-making process. Indeed, the Presidential level participates only in a few, select policy decision efforts. There is some support in the literature that decisions are made at the managerial level, and these constitute well over half of the policies and decisions the government deals with. However, the greater either the perceived difficulty of the problem or the threat, the more likely higher levels are to become involved. The process might begin with th Presidential perception of threat, and the problem works its way down the organizational chain. In other instances, probably the majority, problems well up from below, the presidential or senior level political control has to be exercised over a problem already contextually recognized and defined." (1972, p. 61)

Perhaps an example of how this system works in the forming of goals and courses of action can be seen in the recent SALT strategy. After Nixon came into the White House, an initial decision had to be made on whether or not to proceed with the arms control negotiations which were initiated by President

Johnson. This decision was reached in the White House itself. Once the decision was made, studies were requested from each of the five agencies laid out in the flow chart. An agency control panel in the National Security Council was designated as the coordinator and arbitrator for this task.

Each of the agencies were asked to draft, redraft and debate the issues that they saw in a potential SALT agreement. In addition to this, study channels of informal, ad hoc working groups were set up across agencies to hammer out compromises and inter-agency disagreements. When disagreements existed, multiple positions were presented to the National Security Council whose job it was to return drafts to the agencies after having decided on specific positions which had usually been presented as options in the inter-agency papers.

In this system it can be seen that each of the five agencies acted as adversary teams in which supervision and management was supplied by the National Security Council. As the process developed, a lead agency was assigned to coordinate our negotiating efforts. This agency was the Arms Control and Disarmament Agency with the director, Gerald Smith, appointed head negotiator. While Smith and his supervisory personnel could and did call upon working level assistance from across the agencies, ACDA's responsibility was to manage and coordinate the efforts in negotiation. Thus, in this instance the channeling of alternative options was an upward process from the five agencies themselves.

The designation of specific goals was then recommunicated down the system from the President or the National Security Council and major responsibility for coordination was vested in the Arms Control and Disarmament Agency whose responsibility became managing the working level people involved in SALT. Their responsibility also included the orchestration of the foreign policy process

surrounding the SALT negotiations. They had responsibility to coordinate public relations, negotiation, information to allied nations and communication backup for the decision-making process. This system which seems to have worked so well in the SALT negotiations appears likely to be employed more and more frequently in major foreign policy issues. It is an attempt to develop an inherently bias-free form of decision-making. It seems to provide each of the agencies essentially equal opportunity to present opinions. But it is a slow process, requiring a good deal of lead time which is not always available. In other instances the amount of interaction between the five agencies is much less well coordinated or developed.

The principal reason for policy decision failures in this system appears to be organizational ineffectiveness stemming from an inappropriate handling of knowledge which leads eventually to unsatisfactory policy. Edward Morse states the case succinctly: "Channeling and handling information has become an organizational problem no foreign ministry has mastered." (1970, p. 386)

The United States experience in recent years suggests that the relationship between foreign policy decision-making on the one hand and the information collecting and forecasting on the other is an integral aspect of effective organizational performance. The process suggests that there are patterns of behavior which are strongly influenced by organization position and expectations. Hilsman (1971), for instance, describes organizations in terms of the network of interpersonal relations at various levels. There seems to be a recognized agreement between policy makers and academics on the existence of levels of behavior, on the interaction of motivation and goals, and of the impact of forecasts on preferred modes of action at different levels of the policy process. Some of the elements of these concerns can be made explicit if we introduce modern systems theories which seek to treat organizations as hierarchical

multi-level systems. The concept of a multi-level, hierarchical structure cannot be defined by short, succinct statements. What we propose to do at this point is to (1) introduce some basic concepts for classification and study of hierarchical systems in general, (2) provide a conceptual foundation for the problem of coordination, and (3) indicate some features of hierarchical systems which make them attractive for use in the study of foreign policy decision-making.[11]

To begin with, the total system can be designated as the simple schematic in Figure I plus the ongoing process of foreign policy inputs and outputs (see Figure II). The operation of a subsystem on any level is influenced directly and explicitly from the higher levels, mostly from the immediately superseding level. This influence, while not always binding, tends to reflect a priority of importance in actions and goals of the higher levels. This influence will be termed intervention. The priority of action is oriented downward in a command fashion, but the success of the overall foreign policy system and indeed of the units on any level depends upon the performance of all units in the system. Since the priority of action tacitly assumes that intervention precedes the actions of lower units, the success of the higher units depends upon that action or the resulting performance of the lower level units. Performance can be viewed, therefore, as a feedback and response to intervention. Feedback is oriented upward as shown by the upward arrows in Figure II. We have termed these upward arrows the performance feedback channels. Each of the layers that we have laid out can be broken down into functional decision hierarchies.

The functional hierarchy should contain three layers as shown in Figure III. The lowest level, the selective level, accepts the information from outside the

unit and applies a decision algorithm to derive a course of action. The algorithm must be defined as an organizational means of reaching a solution to a specific intervention from above.

The inherent goal of the second layer activity, the learning and adaptation level, is to reduce uncertainty. Given a set of priorities and goals and the importance of actions from a higher level, this learning or adaptation layer must decide how to respond to the needs prescribed from above. This layer must reduce the uncertainty in making responses and initiatives as much as possible providing a simplified job for the selection level.

The self-organizing layer must select the structure, functions and strategies which should be used on the lower layers so that an overall goal or set of national interest can be pursued as closely as possible. It can change the directions for action of the first level if the overall goal is not accomplished, or it can change the learning strategy used on the second layer if the estimation of uncertainties turns out to be unsatisfactory.

We can formalize the coordination of activities at this point. Consider the process P. It has two inputs: a control of intervention input from the second level (m from a given set M) and an input ω from a given set Ω, called the input. It also has an output y in a given set Y. The process P is assumed to be a mapping.

$$P: M \times \Omega \rightarrow Y$$

Looked at in foreign policy terms the process or selection level concerns the working out of daily actions in each of the bureaucracies involved in foreign policy. The tasks here are to apply an algorithm for responding to stimuli from the environment which has been provided by the second level. While it is true that some policy is made in the "cables" these changes in the algorithms for

responding must be in harmony with the general outlines of objectives passed down from above or there is likely to be requests for a change in activity.

Next consider the second level in our control system. It has two inputs: coordination γ provided by the higher level from a given set Γ, and the feedback z from a given set ξ coming from the process. The output is the control intervention m selected from the set M. The system is a mapping:

$$C_i : \Gamma \times \xi_i \rightarrow M_i$$

At a managerial level the task of coordinating the organizing goals of the Administration with the realities of the daily routine must be carried out. It is here that decisions about the feasibility of particular plans is decided. These levels must provide policy plans for operators to use as algorithms in acting. It is the general case that this level must suggest plans, get them accepted by the Administration and implement them at the selection level.

The highest level is charged with the responsibility of coordination. It has only one set of inputs, namely the feedback information w from the second levels which it uses to arrive at the coordination output γ. The system is assumed to be a mapping:

$$C : W \rightarrow \Gamma$$

where W is the set of feedback information inputs w. Except in rare instances, such as crisis, the Administration level sets national interests, chooses a policy plan or combines suggestions of several plans from the managerial level and assigns responsibility to a lead bureau at the second level, but it does not involve itself in the process directly.

To complete the description of this system we must specify the nature of the feedback information. The feedback information ξ_1 to the second level contains direct information on the process P; it is therefore a function of the control m, the disturbance ω and the output y, given by the mapping:

$$f_1 : M \times \Omega \times Y \rightarrow \xi_1$$

Similarly the feedback information received by the highest level contained information concerning the behavior of the second level and is therefore assumed to be given by a mapping:

$$f_0 : \Gamma \times \xi \times M \rightarrow W,$$

which is a function of the coordination y, feedback ξ and output m.

It should be pointed out that this functional hierarchy is based on the conceptual recognition of the essential functions in a complex decision system. It provides only a starting point for a rational approach to assign proper functions to different layers. In fact, each functional layer can be implemented by further decomposition. For our purposes it is only essential to lay out the elements of the decision-making process and to borrow this functional hierarchy of levels or tasks so that we can demonstrate at what place a specific form of forecasting might be beneficially used. In order to do this, we need to make a set of assertions about the types of planning that each of these levels in a hierarchy must normally concern.

In spite of several common features the tasks and roles of the systems can be delineated by levels at this point.

1. A higher level unit is concerned with the larger portion or broader aspects of the overall foreign policy behavior. In hierarchical

systems terms this is reflected in the fact that a higher level unit is superior to two or more units and the decision of the higher level coordinates the lower levels in accordance with the goal or objective defined over the domains of all the units subordinate to it.

2. The decision period of a higher unit is longer than that of lower units. Simply put, the lower level units are responsible for today's decisions, whether to respond to previous actions or to initiate new actions. The time frame of these decisions are quite limited. However, to evaluate the effect of coordination, higher levels cannot act more often than the lower levels, whose behavior is conditioned by this coordination. Therefore, it is essential to recognize inherent differences of the time frames in most decisions as we proceed up the decision hierarchy. Certainly there are specific strategies or issues such as the Cuban Missile Crisis when the normal process is short-circuited by making most decisions operative at a much higher level in the hierarchy.
3. A higher level unit is concerned with the slower aspects of the overall system's behavior. The lower levels of this decision tree are concerned with more particular local changes in the foreign policy process. The higher levels cannot respond to variations either in the environment or in the process itself which are faster than the variations of concern to the lower levels.
4. Descriptions and problems of higher levels are less structured with more uncertainties and more difficult to formalize quantitatively. Decision problems in the higher levels can be considered as more complex and an approximation can be used to derive a solution to a higher level problem, but accuracy is then reduced. One has to be cautious when interpreting the results.

In general, for any level there is a specific set of techniques suitable for the solution of respective forecasting needs. As we have laid out the system characteristics, units of the higher echelons are concerned with broader aspects of the foreign policy task and therefore have a more complex decision problem than those on the lower levels. They have a longer time frame with which to look at problems, and therefore are concerned with slower aspects of the overall foreign policy behavior. As we turn to specific instances of forecasting techniques and review their qualities we should keep in mind these characteristics so that we can decide at which stage and at which level in the process of foreign policy decision-making and planning forecast techniques are applicable.

The point that needs remphasizing at this stage is that at each of the nodes in Figure II decisions must be made which result in outputs. These decisions are made in part by information supplied about the current state of the process and by goals passed down in the form of interventions or decided upon at this level. But uncertainty exists at each stage and in the process of reaching decisions for action forecasts of the likely impact of these decisions must be made. In certain levels responsibility for dealing with uncertainty is limited to issues with low levels of complexity. This is especially the case at the process level. In issues of higher complexity, managers or senior political officers may be brought into the decision. It is not only the case that different individuals or levels in the hierarchy are involved at different levels of uncertainty but that different routines for handling uncertainty and information in forecasting must be employed. Several of these routines will be described below.

Consensus Forming Techniques

All levels of the bureaucracy attempt to make plans for future action. These plans are obviously based upon forecasts, often more subjective than scientific. It is, however, the case that the forecasts do tend to be of value in the delineating of a plan of action for a specific agency or in the case of the Presidential level for the whole foreign policy bureaucracy. As pointed out previously, the higher one moves in this hierarchy, the less susceptible to quantitative techniques are the questions that are being asked. This is true because they tend to be of a considerably broader nature, dealing with concepts and relations that are much more difficult to pinpoint. Consensus forming techniques for forecasting have been developed for just these types of problems. The techniques attempt to coordinate the joint estimates of experts on the likelihood of a technological development of a social or scientific event occurring in the future. Their major advantages stem from the fact that they use expert opinions under conditions of anonymity so that the social forces in a small group decision making process do not come into play. The most well known of these techniques is the Delphi method. It has generally been employed as a tool to facilitate planning and decision-making in both the hard sciences (Pyke, 1970; Ament, 1970; Enzer, 1971; Schmidt, 1971; Martino, 1972) and the soft sciences (Enzer, 1970; Knorr and Morgenstern, 1968; Helmer and Reascher, 1960). The technique was developed at the RAND Corporation. Their position is as follows:

> "Delphi is a technique of long-range forecasting originated by RAND Corporation senior scientists twenty years ago. In wide use today, Delphi can be applied to define corporate goals, develop a curriculum for higher education, or to predict scientific or technological

breakthroughs. It is done by marshalling the refined opinions of experts through successive interactions of a problem to prove individual answers. These in turn provide better group judgments." (RAND Corporation, 1971)

The Delphi technique employes a panel of experts who, acting without knowledge or identity of other participants, must decide when in the future, if ever, a specific event may be expected to occur. The Delphi experiment may be designed to do any of the following: (1) Specify a probable date or arrangement of dates for the occurrence of an event. (2) Indicate the probabilities and confidence levels associated with the projection. (3) Identify the impact that prior events in the future will have on the occurrence of latter events. (4) Additionally evaluate alternative futures in terms of their feasibility as well as their overall impact for outcome.

There are three basic steps in Delphi forecasting analysis. (1) Selecting an initial questionnaire. It is recommended that questions be selected such that rank ordering of options or the identification of a specific point in time can be provided. Questions which ask for values or opinions requiring paragraphs to develop are inappropriate for Delphi techniques. Thus, if one is developing a Delphi to rank order goals and priorities, one should ask questions about these goals either pairwise or require individuals to rank a set of goals. The initial list of events is usually considered as neither being final or exhausted. Experts may be encouraged to add other questions which they feel are important enough to warrant consideration by the panel.[12]

The use of experts in a Delphi panel is mandatory. One needs to deal with people familiar with trends, problems, capabilities and feasibility of specific events. The decision maker who employs Delphi techniques should feel that he is confident in the collective judgment of the experts he employs. It is quite

advantageous to use experts with differing ranges of expertise. Thus, men who are familiar with the technological aspects of an ABM decision might be combined with those familiar with the political impact of such decisions in order to attempt to assess the much more broad issues involved in ranking of U. S. objectives vis-a-vis ABM sites. One of the criticisms with the use of panels is that creativity and imagination are often stifled by group pressure. Junior men on the panel have a pronounced tendency to defer to their seniors, especially if there are implicit sanctions which are potentially administratable when the decision has been reached. The Delphi method attempts to solve these problems through the strategy of maintaining anonymity of the panel members and thereby eliminating the extraneous effects of reputation, personality and seniority of participants. Guaranteed anonymity is therefore a cardinal rule of the technique.

The actual exercise is conducted in a series of interactions. The first interaction commences when panel members have been presented with the questionnaire. They are asked to make their estimates or give their opinion and return the questionnaire. Once the questionnaires have been returned, the median or average response is recorded and the range of high and low scores is also delineated. In the second round, each participant in the panel receives the same questionnaire plus the information aggregated from the first round, the low, high and median responses on each question. He is asked to evaluate his own initial score in light of this information and to respond again. On this response, however, the individual is also asked to justify his position, if he feels that his answer deviates from the group median. The third commences with each panel member receiving the collected rationale for extreme positions, the median and the high and low scores from the second round and is asked once more to provide estimates for answers for each question. In each of these rounds other sets of

questions may be added to the questionnaire. For instance, each respondent may be asked to provide an estimate of his own reliability or the range of error in his estimate.

Such a technique could be used to identify events which are likely to occur by 1980 and the importance of these events on European security issues such as MBFR or CCD. In order to do this, the estimation of the initial likelihood of the occurrence of each event by 1980 would be needed. Estimation of the cross-impacts among these events is also important and potentially rewarding pieces of information. Decision makers might also want to identify those events where U. S. interaction could change the likelihood of the occurrence, and assess the desirable direction of such interventions. All of these questions could be asked in a Delphi technique and would provide long-ranged information for higher level decision makers.

There are a number of technical aspects which should be considered in implementing this technique but they will not be reviewed here. Those interested in pursuing the technique should consult Helmar (1966), Enzer (1970), or Martino (1972). The technique is particularly applicable where there are no formal methodologies available to provide direct predictions of some future occurrence. It is especially applicable to those complex sets of issues for which the analytical capability of the social sciences is not yet amenable. Shortcomings stem from unreplicability of results; the explicit reasons for a solution developed in a Delphi technique are not opened to experimentation and test. The type of role that Delphi can play in assisting foreign policy planning is associated with the tasks at higher levels of the bureaucracy. The time frame in which answers develop is any where from a day to several weeks, depending on whether all participants are assembled in one location. By its nature, the

technique is less applicable to the "what should we do next" questions of the working level bureaucrat but much more useful in the setting of priorities, considering the likelihood of events, and the impact of the events in the future. Delphi may also be quite appropriate in providing levels of concern for planning documents such as CASP Country Analysis. In this case each of the officers involved with the country may be asked to rank the levels of concern over three iterations.

Trend Extrapolation

Scientific methods based upon analytical models make possible a more objective approach to forecasting. One which can be explained to others and which can be analyzed and criticized by people other than the original forecaster. Roberts has outlined the history of economic forecastings as having passed through five stages, with the sixth stage on the horizon. These stages are:

1. Wisdom, expert or genius forecasting
2. Naive models
3. Simple correlational forecasting models
4. Complex integrated economic forecasts
5. Dynamic causally oriented models
6. The learning models (1969, p. 114)

Delphi techniques are a fine example of expert forecasting. Growth curve and trend extrapolating are naive forecasting techniques in that they do not provide information as to the causal elements or the manipulatable elements in any prediction. They are extremely useful in areas in which the forecaster can feel confident that the past line of behavior, cyclical or linear, will continue into the future. In many instances these techniques are short-range predicting techniques.[13] In some instances, however, where developments seem to take a

rather normal course of action in the same way they have been developing in the past, trend extrapolation can be useful for longer range predictions. The simplest of these techniques is the straight-line projection. Figure IV presents an example of this form of projection. It shows the estimate of top speed of United States combat aircraft as it has grown since 1910. A linear regression line, least squares, fits this data extremely well. The regression of speed and miles per hour on time is:

$$Y = -18.30568 + .06404\ T$$

The correlational coefficient is .98580 and the standard error of the regression coefficient is .00193. Barring drastic breakthroughs in flight propulsion, extrapolations into the future can be based on this same equation. There are dangers, however, in proceding in this manner. See for instance, Figure V on the gorwth of kill power in waspons sytems over time. Such inventions as the atomic bomb have seriously thrown the normal simple linear model off considerably.

Slightly more sophisticated techniques are based upon cyclical assumptions. Business curves frequently rely upon seasonal oscillations in the economy as well as many specific non-seasonal but occupational oscillations. These techniques have proven beneficial in forecasting economic impacts of various tariff positions on U. S. industry. One particularly interesting account stems from a disagreement with the Japanese tile industry over their production of building tiles for ceramic tile bathrooms. Economic analysts in the State Department confirmed Japanese claims that the Japanese and U. S. oscillations in production were prefectly out of phase such that Japanese supplies hit U. S. markets when U. S. manufacturers could not supply the demand. Indeed continued use of Japanese tile increased their demand without affecting U. S. manufacturers' markets, thereby making the free import of Japanese tile a positive benefit.[14]

The systems analysis group in the office of Secretary of the Defense has used several trend analyses in looking at the Vietnam war. These analyses have proven beneficial for short-run predictions of supplies from the North and likely shifts in the current level of activities in specific areas. Charles McClelland at the University of Southern California has been experimenting with various cyclic descriptions of the foreign policy exchanges between a number of key nations in the world. While these methods are widely used, and extremely useful, it must be recognized that they have the following serious shortcomings:

1. They are unable to give warning that there has been a significant shift in the conditions which produce the past behavior. Predictions from the past could be extremely inaccurate.
2. They are unable to predict the outcome even when it is known that one or more possibly important conditions are going to be changed in the future. This is true even when that change is recognized to be likely to produce an alteration in the rate of advancement.
3. They are unable to give policy guidance as to what conditions should be changed or manipulated and by how much, to produce a desired change in the rate of growth or decay in whatever trend is being predicted.

We cannot dismiss, however, those who accept or advocate trend analysis so easily because of the time constraints on the decision process. Martin Schubek asserts:

"There are the chartists and the fundamentalists. The fundamentalists want to discover as much as they can about the firm--where its technology is going and so forth--while the chartists draw some linear extrapolations of what is going on and invent such phrases as 'when the thing has heads and shoulders.' You cannot idly dismiss the chartists, because in one sense, a key to forecasting is the amount of time one has available in the decision process to make a statement about the future. A chartist can

come up with some sort of fairy tale in ten or fifteen minutes. If you do not have more time, pherhaps that is the best you can get." (In Bell, 1964, p. 945)

Given constraints on foreign policy decision-making where time is of the essence, looking at the trends and visually, unmathematically extrapolating the likely events in the future if things go unchecked might be an excellent first approximation to developing early warning systems. McClelland has argued that we can identify the growth of crises this way by watching the communication between hostile nations overtime and he has also demonstrated that shifts in the pattern of interaction do signal changes in strategy. (1961) These short-range forecasts of imminent change in system performance seem to be potentially advantageous to working levels in the bureaucracy where time is of the essence and actions are broken down to their smallest unit of analysis.

Correlational Forecasting Models

Where more time is available, however, other techniques may be more beneficial. The fundamentalists, as Schubick calls them, believe that at least some of a number of potential variables exhibit interdependencies in general which are sufficiently important that they must be taken into account in making any prediction. From a policy standpoint, regression and correlational techniques allow the identification of independent variables which are potentially usable as actions that one country, in this case the United States, could employ to increase or decrease a dependent variable which in this case would be some observable performance measure associated with a national interest. Analysts can attempt to account for variance in one specific variable by applying correlational or regressional techniques to a set of variables at a cross-section in time or over time.[15]

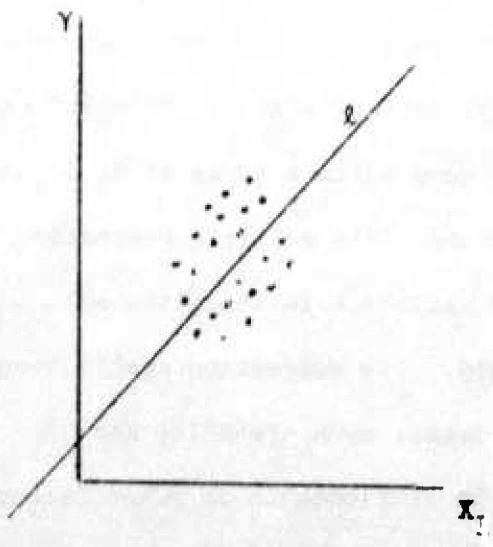
In scientific research, we work with what are called independent and dependent variables, the former being the "causes" of a given social phenomenon and the dependent variables being the phenomena "caused." (Caused here is not used in any strict sense; at times we have only a notion that one variable is related and prior to another phenomenon.)

The regression model is an attempt to predict with maximum efficiency, the value of a dependent variable from one or more independent variables. In rough mathematical notation, this may be expressed:

$$Y = \alpha_1 + \beta_1 X_1 + \beta_2 X_2 + . . . \beta_n X_n,$$

where Y stands for the dependent variable and X's for independent variables. The specific relationship between the independent and dependent variables is designated by the α values in the above equation. Each α weights the independent with which it is associated according to the impact which that independent variable has on the dependent variable. These β values are frequently designated either as b or β and are called regression coefficients or beta weights.

Assume for the moment that we have one independent and one dependent variable. Then the cases which we are studying can be plotted graphically, for example:



the goal of linear regression in this case is to draw some line through these points in such a way as to maximize the efficiency of our predicting Y from X_1. Although this line may be a curve, assume that it is the straight line ℓ drawn in the diagram. Our prediction of Y values in this case is most efficient if ℓ, the sum of the distances from each point to the ℓ is a minimum value.

Once such a line is determined, there are at least three different questions we may ask: (1) What is the impact of X_1 on γ ? In other words, how much of a change in γ is initiated by a one unit change in X? The answer to this is given by the regression coefficients mentioned above. In the chart our regression coefficient will be positive--an increase in X is associated with an increase in γ . (2) How well can we estimate γ values using X_1 values and our regression line ℓ ? This question is given to us in summing the squared deviations of the points from the line and dividing that number by the number of cases. In other words, we calculate the average squared error with which we estimate γ . This number is called the standard error at estimate. (3) What percentage of the variation in γ values can be accounted for by our independent variable X? This last question brings us into the related question of correlation. If we wish to know the correlation between X and γ , we are finding the degree to which high values of X occur with high values of γ and to which low X values occur with low γ values. One coefficient for determining this degree of covariation is the Pearson product moment correlation. If the correlation = 1.0, X and γ values are completely covariant; if it is = 0.0, the γ values are randomly dispersed without regard to X values. Further, when this correlation is squared, it indicates how well X accounts for the variance in γ .

Suppose we were interested in finding out the impact of U. S. aid upon the stability and development of a particular country, perhaps Brazil. We could regress variables for development or political stability upon various types of U. S. economic and military assistance to Brazil over time. The multiple regression correlation would tell us what percentage of the variation in stability or development was associated with U. S. economic aid. The regression coefficients would specify which type of aid had the largest impact upon stability and development. Unexplained variation, $1-r^2$ would be attributable to other factors, perhaps even observational area.

The most important consideration in applying regression techniques is that the independent variables be selected because they are manipulable by U. S. policy processes. In forecasting for planning, the relative importance of a variable should be considered both from the technical, statistical standpoint of a strong regression coefficient and from the policy standpoint of being a variable which the U. S. can actually manipulate. Thus, variables such as world public opinion, number of nations in an alliance, economic development or political stability may be only slightly manipulatable by the United States. On the other hand, there are other variables such as the various types of aid and diplomatic recognition, all variables which the United States can more easily choose to employ. Regression coefficients are properly used to estimate population parameters only when the structure of a model employed in forecasting is well specified. Brunner (1970) demonstrated very convincingly that the data and strategies presently employed by most political scientists (such as regression analysis) will usually not reveal the underlying structure of a model. This is generally the case whether the systems are analyzed cross-nationally at a point in time or individually as a time series.

While regression techniques are not applicable where the questions addressed, attempt to describe all or a significant aspect of the future, they are quite appropriate when one is designating a well-sepcified problem in which the components are easily identified. When the analyst wants to know the consequences of changing U. S. commitments or actions on a specific host country and he is reasonably sure that he has specified all relevant variables, regression techniques can be employed. Their advantage over trend techniques is that they do identify causal elements which can be manipulated. Such problems as those addressed by the inter-agency committees whose task is to coordinate military and economy

assistance may benefit from regression analyses to identify expected impacts of various assistance programs. The questions of the impact of arms transfers might also be amenable to such regression techniques. The forecasts in these cases form background information for identifying expected performances of national systems when aid or arms transfers are contemplated. These expected performances can be compared with goals and interests on a country-by-country basis to identify or rank various strategies vis-a-vis a particular country.

Dynamic Causally Oriented Models[16]

Most attempts to generate an explicit model of foreign policy behavior, on the part of academics, have relied upon linear relations among relatively few variables (e.g., linear regression models and factor analysis). These models have advantages over mental images of foreign policy interactions since they have specified sets of assumptions about the relations between these variables which can be checked by resorting to data analyses. These assumptions of linearity provide fairly accurate short-term (several years) projections since any curve, over a short enough interval, can be approximated by a straight line. However, the longer into the future the projections are made, the greater will be the likely error, just as in the case for trend extrapolation. In designing long-term planning systems, the analyst must be prepared to work with non-linear systems. One problem with non-linear systems is the lack of methods for solving such systems analytically. However, solutions can be reached through the use of computer simulations. These simulations provide information about the overtime implications of the defined alternatives. Moreover, they will allow the manipulation of the variables and relations to test the relative, long-range impacts of various policy alternatives. These simulation models require that the

variables be categorized as to whether they are manipulatable or non-manipulatable and as to whether they are exdogenous or indogenous;

1. Manipulatable Variables are directly controllable by U. S. government.
2. Non-manipulatable Variables may vary by functions by other variables in the models but are not directly controlled by U. S. actions.
3. Exogenous Variables effect but are not affected directly by relations specified in the system.
4. Indogenous Variables affect other variables and are in turn affected by other variables in the system.

A set of variables representing each subset of manipulatable exogenous, non-manipulatable indogenous, and non-manipulatable exogenous variables can be identified. Manipulatable indogenous variables are illogical from a standpoint of policy planning. The design variables should be ordered by a set of relations which would, in part, be identified by long-range planners and could be used to construct such simulation based upon data currently available. These relationships would be an explicit attempt to formalize the mental images used by policy makers in currently making decisions on what U. S. courses of actions should be based upon and expectations of the effect of these courses of action.

Thus, within the system, each variable would be in one of the following vectors:

M^x_i = vector of manipulatable exogenous variables

U^n_i = vector of non-manipulatable endogenous variables

U^x_i = vector of non-manipulatable exogenous variables.

These variables are related by some set of relations, f. Thus:

$$f(M^x_i, U^n_i, U^x_i) = \text{"The System"}$$

An example might be helpful both in illustrating the vocabulary just developed and in introducing several important concerns which differentiate this project from previous efforts.

Imagine a policy planner who is very interested in what makes people in a nation "satisfied" or politically stable. After doing some preliminary discussion, the following three variables are decided upon as being the important concerns:

S_t = overall satisfaction level of the people in a given nation at time t

E_t = performance of the economic sector of the nation at time t

G_t = performance of the government of the nation at time t

In addition to the identification of important variables you must define a set of relationships between these variables: a structure of the system must be given. Our political analysis stipulates the system structure with the following equations:

1. $E_t = \alpha \, S_{t-1}$
2. $G_t = \beta \, (E_t - E_{t-1})$
3. $S_t = G_t + E_t$ where α and $\beta \geq 0$

Equation 1 states that economic sector performance will be proportional to the preceding period's level of overall satisfaction. Equation 2 tells us that government performance will be proportional to the change in economic sector performance from this period to the preceding period. Finally, 3 is an accounting equation which defines overall satisfaction as the sum of government performance and economic sector performance. (Throughout this discussion it will be assumed that S, E, and G are measured in comparable units.)

The endogenous non-manipulatable variables of the system are G, E and S and the state of the system at a particular point in time is therefore given by

listing values of each variable at that time: G_t, E_t, S_t. Variables which are not included in the system are called parameters. An "effective" parameter is one which has a discernible impact upon the system's behavior (e.g. α , β , and t in the set of equations above). The above set of equations describes a dynamic system since the system is effectively parameterized by time.

The values of α and β for a particular nation might be estimated by observing the overtime values of S, E, and G. As Brunner points out, the data analysis problems associated with this estimation are by no means simple. However, let us assume an awareness of the problems, from tasks I and II; then from data for the period 1966-71 we estimate $\alpha = 0.5$ and $\beta = 0.0$. We can now use equations 1-3 together with these estimates of α and β to make the following predictions about future system behavior:

Table 1

Results of Equations 1-3 When $\alpha = 0.5$ and $\beta = 0.0$

$\alpha = 0.500$ $\beta = 0.000$

	T	S(T)	E(T)	G(T)
Already Observed	1966	1.000	0.000	0.000
	1967	0.500	0.500	0.000
	1968	0.250	0.250	0.000
	1969	0.125	0.125	0.000
	1970	0.062	0.062	0.000
	1971	0.031	0.031	0.000
Predicted	1972	0.016	0.016	0.000
	1973	0.008	0.008	0.000
	1974	0.004	0.004	0.000
	1975	0.002	0.002	0.000
	1976	0.001	0.001	0.000
	1977	0.000	0.000	0.000
	1978	0.000	0.000	0.000

Since the consequences of having satisfaction or stability, $S(t) = 0$ are usually thought to be undesirable, the results reflected in Table 1 may be viewed with alarm. Accordingly, the question becomes what policy advice can be given. This in turn rests upon assumptions about the relationship between actions open to the U. S. with respect to this particular country (the manipulatable exogenous variables) as well as assumptions about other nations' attempts to influence outcomes in that country (non-manipulatable exogenous variables).

Suppose that we know that α is a function of U. S. technical assistance in terms of mass communications programs and that β is a function of heavy industrial capital. This knowledge enables us to specify an activity which would increase the values of α to 0.8 and β to 3.0. Then for the value of $S(t)$ set at 1.0 for one time period, our original equations predict that the people's satisfaction will rise in the quasigeometric fashion traced in Table 2.

Table 2

$\alpha = 0.800 \quad \beta = 3.000$

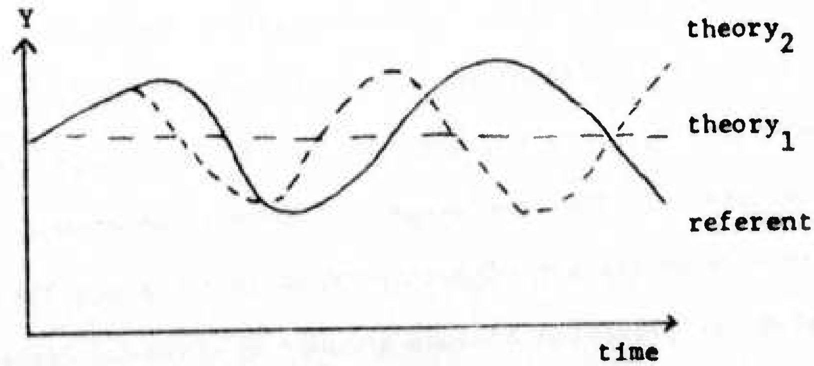
T	S(T)	E(T)	G(T)
1	1.000	0.000	0.000
2	3.200	0.800	2.400
3	7.840	2.560	5.280
4	17.408	6.272	11.136
5	36.890	13.926	22.963
6	76.267	29.512	46.756
7	155.521	61.014	94.507
8	314.625	124.417	190.208
9	633.549	251.700	381.879

Table 2 assumes no change in the non-manipulatable exogenous variables for simplicity. But the impact of a policy upon one nation must be weighted against its impact on U. S. objectives in other countries as well. To state an obvious point, finances and national security place limits upon both the quality and quantity of foreign involvement. Since this is the case, optimization on a

country-by-country basis will generally yield greatly sub-optimal global results. For example, U. S. policy toward Brazil maybe an exogenous variable affecting Chile's relations with the United States. These other country impacts must also be taken into account in long-range planning.

The role of forecasts and their accuracy in the policy planning process introduces some difficult questions in terms of the definition of accuracy. Accuracy has at least two meanings. Theories should not be evaluated and compared exclusively on the accuracy of their point-in-time predictions. It is neither a necessary nor sufficient condition for a theory well-suited to yielding policy advice. For the purposes of making policy recommendations, we might prefer a theory which makes point-in-time predictions which are less accurate than those made by another theory.

Consider the following example drawn from Forrester's Industrial Dynamics (1970) as seen in Figure VI.



Suppose we somehow know (perhaps we are told by a genie) how an important variable in the referent behaves over time. This behavior is represented by the solid line in Figure VI. There are two "competing" systems (or alternative theories about two structurally different systems) which purport to relate the variable with time. The "predictions" of these two theories are illustrated in Figure VI by

dotted lines; theory$_1$ by a horizontal straight line and theory$_2$ by a slowly growing sinusoid which has a period of fluctuation about 25% shorter than that of the referent.

Which is the better theory? The answer clearly depends upon the theorist's objective. If the purpose of the theory is to predict values of the variable at closely spaced points in time in such a way as to minimize the sum of the squared deviations between predicted and observed values, then we would prefer the straight line predictions of theory$_1$.

However, if our objective was to predict how changes in the system would affect the system's output, we should be very reluctant to employ theory$_1$. Although theory$_2$ yields point-in-time predictions which are inferior to those of theory$_1$, it better reflects the dynamic character of its referent and therefore appears to be a better guide to "desirable time points at which to introduce policy changes.

In short-range prediction, minimizing random events and error in point prediction may be a beneficial goal in planning, but it is not decisive to argue that random events will destroy the accuracy of long-range predictions or that one could not predict 1970, for example, from what we know about 1930. This is not decisive because the aim of such efforts is not a precise blueprint of the real future, rather the provision of some grounds by which we can make present planning choices more sensibly. These choices may themselves undermine the accuracy of any prediction, but that is not nearly as significant as the fact that predictions are absolutely necessary if we are to be able to take account of the long-run and what we do now. Joseph Martino argues the point well:

"This view of the measure of goodness of forecasts must be accepted by both decision maker and forecaster. If the decision maker insists on

judging forecasts on the basis of whether or not they come true, he may find himself in trouble. Some poor forecasters in view of the self-fulfilling and self-defeating paradoxes have advocated what amounts to protective action. They advocate that the forecaster take into account people's probable reactions to the forecast, and then state the forecast in such a way that it will seem to have been correct. The end result of such a procedure would be to make forecasts completely useless for decision-making. They would become like those of the Delphic oracle, which have been described as vague and ambiguous, allowing room for different interpretations. Or worse, they might become like those of Al Cap's character, Old Man Moose, whose forecasts are so confusing that they can't be understood until it's too late. A forecaster would be proven right by events, but his forecasts would be of no benefit to anyone. Thus, the decision maker who wants to continue to receive competent, professional advice from his forecasters must judge the goodness of that advice in terms of its utility for decision-making, not in terms of whether the forecast eventually comes out true. Likewise, forecasters must recognize that his objective is to be useful, even if this means being wrong." (1972, p. 13)

In interviews with the Arms Control and Disarmament Agency a sage systems analyst charged with the task of forecasting likely outcomes of various arms control measures both in SALT negotiations and in upcoming MBFR negotiations commented that perhaps the most important point to keep in mind was that the forecaster works for a client. Answers to questions for his client, drive all of the forecasting that he contemplates. Forecasts performed in a vacuum, while perhaps interesting, are usually worthless. These comments emphasize the role

of utility in estimating the value of any specific forecasts. While the criteria of utility is certainly the final arbitor on the use of a specific technique, let us attempt to categorize the forecasting continuum into several arbitrary levels so that we can make suggestions as to the potential application of the various techniques reviewed in this chapter. For the sake of simplicity consider four problems which divide the continuum of forecasting:

A: What Effort

B: What Success

C: What Can We Do

D: What Are the Future Implications

In Problem A, What Effort, the question to be answered by the forecaster is: which of an infinite number of unknowns could be addressed with current resources: Which of these would likely have the greatest payoff? This problem is one of the most difficult to resolve. It requires the strongest concentration of experts and wisdom judgment. It is the area in which consensus-forming techniques, as the Delphi, are likely to be their largest success.

In Problem B, What Success, we are typically concerned with describing the state of the art. The problems typically encountered in forecasting in this area are questions: in which particular areas of a problem can changes be expected to occur. In this area a mix of three types of forecasting seems potentially relevant. Certainly consensus-forming techniques are still quite applicable. Trend analysis may demonstrate that recent shifts indicate drastic changes in activity or development. And regression models may specify which variables to manipulate in order to achieve greatest success.

In Problem C, What Can We Do, we are concerned with applications. The systems of interest are not necessarily physical systems such as ABM's. They

include political, economic and social systems as well. It is here that the forecaster must bring together relatively independent streams of events and envision a possible merging of interactions to achieve some end. It should be apparent that forecasts prepared on Problem C, What Systems, require models which are in order of magnitude greater in the number of concepts and relations than those required in A or B or are of a unique caliber. It is thus essential that highly specified regression techniques be used or non-linear systems and simulations be relied upon for forecasts.

The final problem area, What Are the Future Implications, is effectively inclusive of all others but is also unique. These are the problems where one attempts to describe all or a significant aspect of the world of the future. That is ten or more years away. Of particular interest in this area is the unanticipated conseqeunces of decisions. Therefore, we really have to deal with Problem D in resolving the combined impact of other problem projections in a long-range period.

In Problem D the resolving of the combined impact of other problem projections in the long-range period, means several things. First, anyone or any part of the problems in A, B, or C, is reduced in visibility and relative significance in this problem area. Second, the descriptions of the future are likely to be more qualitative in nature. And third, the reliance on point predictions and event predictions is significantly reduced. The requirement becomes one for generalizations as opposed to specifics. It is for this problem that the technique of complex non-linear feedback approaches have been developed and are most likely to have greatest payoffs.

Conclusion

This chapter has attempted to delineate a formal specification for the decision-making process in foreign policy bureaucracies and to use that delineation for the discussion of the role of forecasting and policy planning for foreign affairs. The strategy employed was to delineate the types of decision processes that occur at various levels in the decision process and to specify the planning that was essential in each level of the decision process. Specification of planning then led to the requirements for each planning activity in the way of forecasting information. Against this set of requirements the various forecasting strategies available were reviewed and through the technique of specifying decision problem types, suggestions were made as to the applicability of a set of alternative techniques.

It is no secret that attempts to formalize the decision process, especially in the area of policy planning and forecasting for planning, is not viewed without alarm by policy planners. By way of defense, let me conclude this chapter by pointing out the most compelling reasons for accepting the point of view put forth here.

Halprin (1973) has pointed out that the planning status of various agencies in Washington vary, in terms of their capabilities, in direct relationship to the amount of resources that the agency in which the planning is being done is responsible for. If this is the case, those who have the largest slice of the pie, the military, would be expected to have the most sophisticated planning status. Halprin is obviously correct in this respect. It can also be pointed out that forecasting for planning in the military is essential since budgetary cycles and research and development costs require relatively long-range commitments to weapon systems. Thus it takes five to ten years of developmental costs for a

weapon system to be fully operational. This raises the question as to whether it is advantageous for the military to have the best policy planning staffs. The question verges on an ethical point on which several pages could be devoted. It is not the ethical question, however, that I wish to address. Rather, it is the implication for inter-agency disagreements that such a differential in planning must entail.

The hierarchical control system model presented in this chapter emphasizes the need for coordination at high levels in the policy bureaucracy, if actions on the part of multiple decision units are to be integrated. Thus, when managerial level concerns are contradictory between agencies, information must travel up the system to the NSC or other offices at higher levels in the bureaucracy. Unfortunately, the decision strategy employed by the agencies in this game is that akin to a poker player. Each hand is played to be won. An ABM question is fought out and won or lost; the B-1 bomber is approached in the next hand.

The implications of this chapter are that a chess strategy is much more likely to succeed. In other words, certain arguments are worth losing to protect more central or intrinsic goals. The development of chess strategy requires that longer range planning be instigated. Halprin's point is that long-range planning is well developed where agencies are responsible for large resources. Thus, not only are these agencies pursuing chess strategies, they are essentially not defeatable by a poker strategy in the long run.

The point may not be made only with regard to inter-agency concerns, however. It seems obvious that the strategies of a good chess player are required in dealing with other nations. Poker is not a good model for the long-range problems that face foreign policy decision-makers. In responding to the policy actions of other nations simple algorithms can be used by working level diplomats which may,

over the short run, appear to be poker strategies. It is essential, however, that managerial level and supreme control units instigate strategies akin to those of a chess player. As these strategies of coordination, in terms of our foreign policy effort, become well recognized, forecasting will tend to be taken more seriously in the planning efforts. Not only will forecasting be employed more frequently for planning, but the range of the forecasts ought to increase as the importance between plans and actions increases and as the process moves up the hierarchy in the decision process.

The implementation of these tasks is not considered a panacea by any means. Nor is it expected that the speed with which techniques similar to those delineated here will be adapted, with anything approaching the speed of light. Others. have discussed the difficulties and possible approaches in applying academic skills to policy decision-making.[17] The optimum solution is not in sight. It may seem an evasion to paraphrase Mao Tse Tung and assert that the only way to learn about forecasting is by making forecasts, but this rightly understood, is the heart of the matter. Such developments as a Joint Long Range Strategic Study and the CASP country analysis papers point the directions. The future is inevitable.

FOOTNOTES FOR FORECASTING FOR POLICY

1. The types of planning discussed here were suggested,by Puckett,1972. For review and critique of Puckett's position see Hilliker (1972).

2. For an extensive review of the CASP and PARA system see Bendix research reports on PARAS.

3. Reviews of forecasting efforts include Bendix, 1972, Tanter, 1970, and Geiger and Hansen,(1968)

4. This position is well developed in Forrester, 1971.

5. Axelrod (1973) surveyed bureaucratic decision making officials responsible for military assistance programs and found that forecasting is a routine operation. He also found definite organizational biases.

6. See Tanter and Ulman, 1972, Bobrow, 1972, Choucri and Robinson, 1973, Rummel, 1970, and Hermann, 1972.

7. This point is supported by Geiger and Hansen, 1968, Axelrod, 1973, and Forrester, 1971.

8. Users have demonstrated an interest in more effective employment of academics. The Military Operations Research Seminars have faced the problem in the forecasting for planning workshops, the Advanced Research Projects Agency has supported and is continuing to support conferences to bring users and academics together. Various models for this intergration can be found in Havelock 1971 and 1972.

9. The Arms Control and Disarmament Agency, the State Department, and The Advanced Research Projects Agency of the Defense Department are all supporting contracts which would attempt to identify areas of utility from the research community for their needs.

10. The classification of foreign policy actors relies upon Stemple's (indem) suggested typology. A slight modification of this typology is developed here.

11. The development of this application of control theory stems from the work of Mesarovic et. al. 1970. For other suggestions of similar approaches see Steinbrunner (1973) and Burgess (1972).

12. An excellent and simplified introduction to the potentials of the Delphi technique can be found in Benson 1972.

13. For a review of the advantages and disadvantages of these techniques see Young, 1970. For a fine discussion of the methodologies involved see Martino, 1972.

14. This example comes from personal discussions at the Foreign Service Institute Course in Quantitative Approaches to Foreign Policy.

15. For a view of the techniques involved see Ezekiel and Fox (1959) and Draper and Smith (1966).

16. The next five pages are adapted from Phillips and Thorson; Research Proposal to the Advanced Research Projects Agency.

17. See Hermann, 1972, Stemple, indem, and Bobrow, 1971.

BIBLIOGRAPHY LIST

Allison, Graham T. (1971). Essence of Decision: Explaining the Cuban Missile Crisis. Boston: Little, Brown.

Ament, Robert H. (1970). "Comparison of Delphi Forecasting Studies in 1964-1969." Futures. Vol. 2 No. 1, (March), pp. 35-44.

Axelrod, Robert (1973). "Bureaucratic Decisionmaking in the Military Assistance Program: Some Original Findings" in Halperin and Kanter (eds.) Readings in American Foreign Policy, Boston: Little, Brown.

Bell, Daniel (1964). "Twelve Modes of Prediction of a Preliminary Sorting of Approaches in the Social Sciences." Daedalus, Vol. 93, (Summer), p. 850.

Bendix, Office of National Security Studies (1972). Project PARAS.

Benson, Dennis Keith (1972). "Delphi Forecasting Techniques: Introduction and Overview." Project CAFE Memorandum #35. Behavioral Science Laboratory. The Ohio State University.

Bobrow, Davis (1971). "Analysis and Foreign Policy Choice: Some Lessons and Initiatives." Paper prepared for American Political Science Association annual meeting.

Brunner, Ronald P. (1970). "Data Analysis, Proven Analysis and System Change." Paper prepared for the 66th Annual Meeting of IPSA.

Burgess, Phillip (1972). "Notes on a 'Design Theory' Perspective in Social Research." Unpublished mimeographed paper.

Choucri, Nazli (1973). Forecasting in International Relations: Problems and Prospects, MIT mimeo.

__________ and T. Robinson (eds.) forthcoming Forecasting in International Relations: Theory, Methods, Problems, Prospects.

Davis, David (1972). How Bureaucrats Make Foreign Policy. Lexington: CC. Heath.

Draper, N.R. and H. Smith (1966). Applied Regression Analysis. New York: John Wiley & Son.

Enzer, Selwyn (1970). "A Case Study Using Forecasting as a Decision-Making Aid." _Futures_. Vol. 2 No. 4, (December), pp. 341-362.

__________ (1971). "Some Development in Plastics and Competing Materials by 1985." Institute for the Future Report R-17(January).

Ezekiel, M. and K. A. Fox (1959). _Methods of Correlational Regression Analysis_. New York: John Wiley & Sons.

Forrester, Jay.(1971). _World Dynamics_. Cambridge: Wright Allen.

Geiger, T. and R.D. Hansen (1968). "The Role of Information in Decision Making on Foreign Aid" in Baver (Geiger ed.) _The Study of Policy Formation_. New York: Free Press.

Halperin, Morton. (Forthcoming). _Bureaucratic Politics in International Politics_.

Havelock, Ronald (1972). "The Role of Research Communities in National Problem Solving." University of Michigan mimeo.

__________ (1971). "The Utilization of Education Research and Development." _Journal of Educational Technology_, Vol. 2 no. 2.

Helmer, Olaf (1966). _Social Technology_. New York: Basic Books, Inc.

__________ and N.H. Rescher (1960). "On the Epistomology of the Inexact Sciences." RAND Corporation Report R-353, (February).

Hermann, Charles F. (1971). "The Knowledge Gap: The Exchange of Information Between the Academics and the Foreign Policy Communities." Paper prepared for the American Political Science Association annual meeting.

__________ (1972). "Policy Classification: A Key to the Comparative Study of Foreign Policy." In Rosenau, Davis and East, _The Analysis of International Politics_. New York: The Free Press.

Hilliker, Grant (1972). A Communication: On "American Foreign Policy Planning." Mershon Mimeo.

Hilsman, Roger (1971). _The Politics of Policy Making in Defense and Foreign Affairs_. New York: Harper and Row.

Knorr, Klaus and Oskar Morgenstern. (1968). "Political Conjecture in Military Planning Policy Memorandum No. 35." Center of International Studies, Woodrow Wilson School of Public and International Affairs, Princeton University, (November).

Lenz, R.C., Jr. (1962). Technological Forecasting. USAR Aeronautical Systems Division, Technical Report ASK-TDR-62-414.

Martino, Joseph P. (1972). Technological Forecasting For Decisionmaking. New York: Elsever

McClelland, Charles A. (1961). "The Acute International Crisis." World Politics. Vol. 14 (October), pp. 182-204.

__________, Daniel P. Harrison, Wayne R. Martin, Warren R. Phillips and Robert A. Young (1965). The Communist Chinese Performance in Crisis and Non-Crisis: Quantitative Studies of the Taiwan Straits Confrontation, 1950-1964. China Lake, California: U.S. Naval Ordinance Test Station, NOTS TP 4138,(May).

__________, Rodney G. Tomlinson, Robert G. Sherwin, Gary A. Hill, Herbert L. Calhoun, Peter H. Fenn, and J. David Martin (1971). The Management and Analysis of International Event Data (September).

Mesarovic, M.D. et al (1971). Theory of Hierarchial Multilevel Systems. New York: Academic Press.

Morse, Edward (1970). "The Transformation of Foreign Policy." World Politics. Vol. 43, pp. 371-392.

Puckett, Robert (1972). "American Foreign Policy Planning." Foreign Service Journal. Vol. 49 (July), pp. 12-14.

Pyke, Donald L. (1970). "A Practical Approach to Delphi." Futures. Vol. 2 No. 2 (June), pp. 143-152.

RAND Corporation (1971). A Bibliography of Selected Rand Publications--DELPHI." Santa Monica: RAND Corporation (July).

Roberts, E.B. (1969). "Exploration and Normative Technological Forecasting: A Critical Appraisal." Technological Forecasting. Vol. 1, pp. 113-127.

Rothstein, Robert L. (1972). Planning, Prediction and Policymaking in Foreign Affairs. Boston: Little Brown.

Rummel, R.J. (1969). "The D.O.N. Project: Policy Relevance and Overview." D.O.N. Research Report 34. University of Hawaii.

Schmidt, D.L. (1971). "Creativity in Industrial Engineering." RAND Corporation Paper No. 4601, (March).

Steinbruner, John D. (1973). "New Dimensions of Political Analysis." Harvard Mimeo.

Stempel, John (1972). Theory and Practice in Foreign Affairs: Why Two Worlds Seldom Meet. (indem)

Tanter, Raymond (1972). "International System and Foreign Policy Approaches: Implications for Conflict Modeling and Management." World Politics. Vo. XXIV, pp. 7-39.

_________ "The Policy Relevance of Models in World Politics." Advanced Research Projects Agency Research Report No. 7. Washington: Office of Naval Research.

Tanter, Raymond and Richard H. Ullman (1972). Theory and Policy in International Relations. Special Supplement to World Politics, (Spring). Later published under same title by Princeton University Press.

Young, Robert A. (1970). "Prediction and Forecasting in International Relations: Some Theoretical Issues." WEIS Technical Report #5. University of Southern California.

Yule, G.V. and M.G. Kendall (1950). Introduction to the Theory of Statistics. London: Griffin.

Weaver, W. Timothy (1970). "Delphi as a Forecasting Tool." Notes of the Futures of Education. Vol. 1 No. 3 (Summer), pages 7-10.

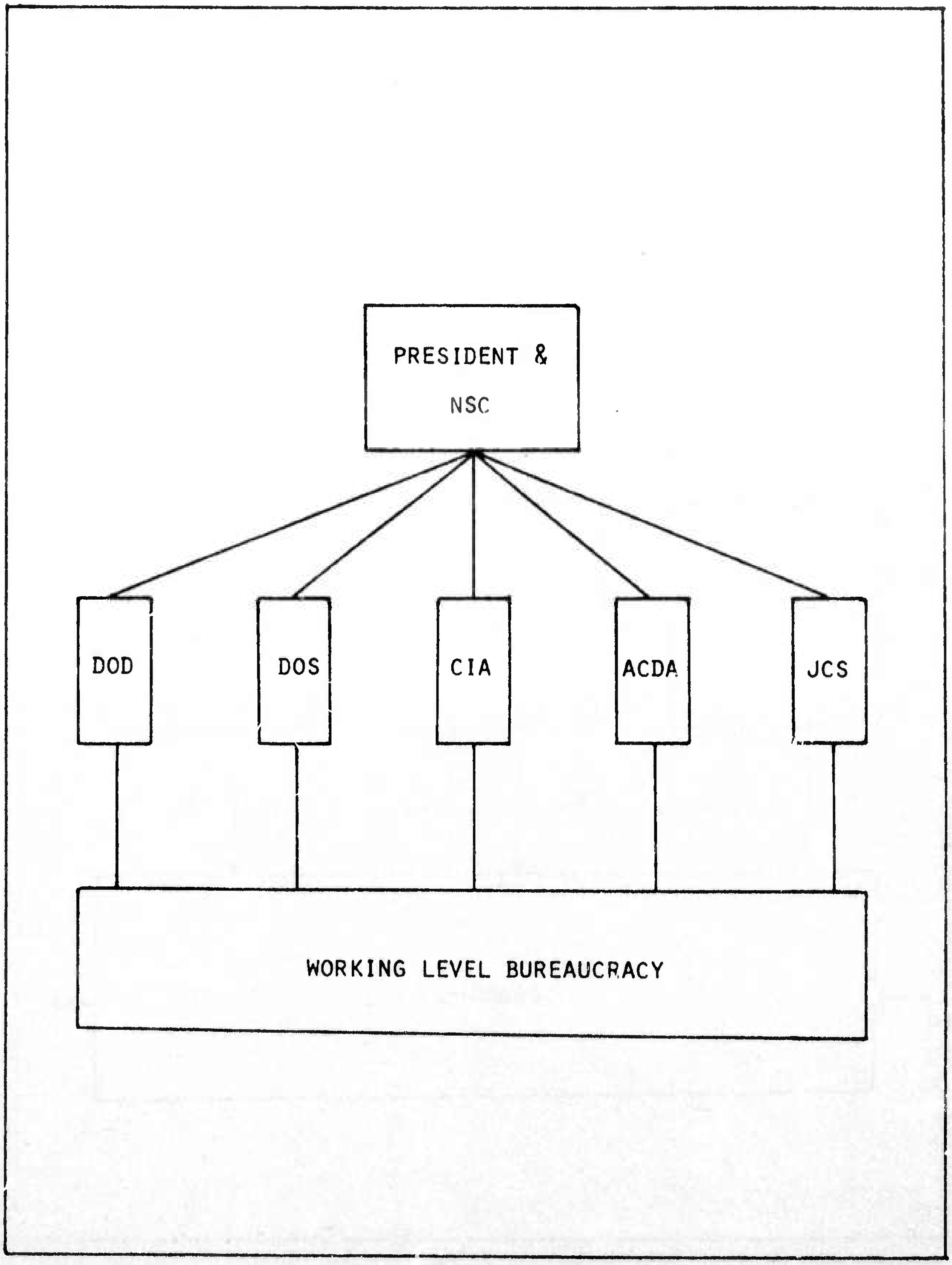


FIGURE I - THE FOREIGN POLICY DECISION-MAKING HIERARCHY

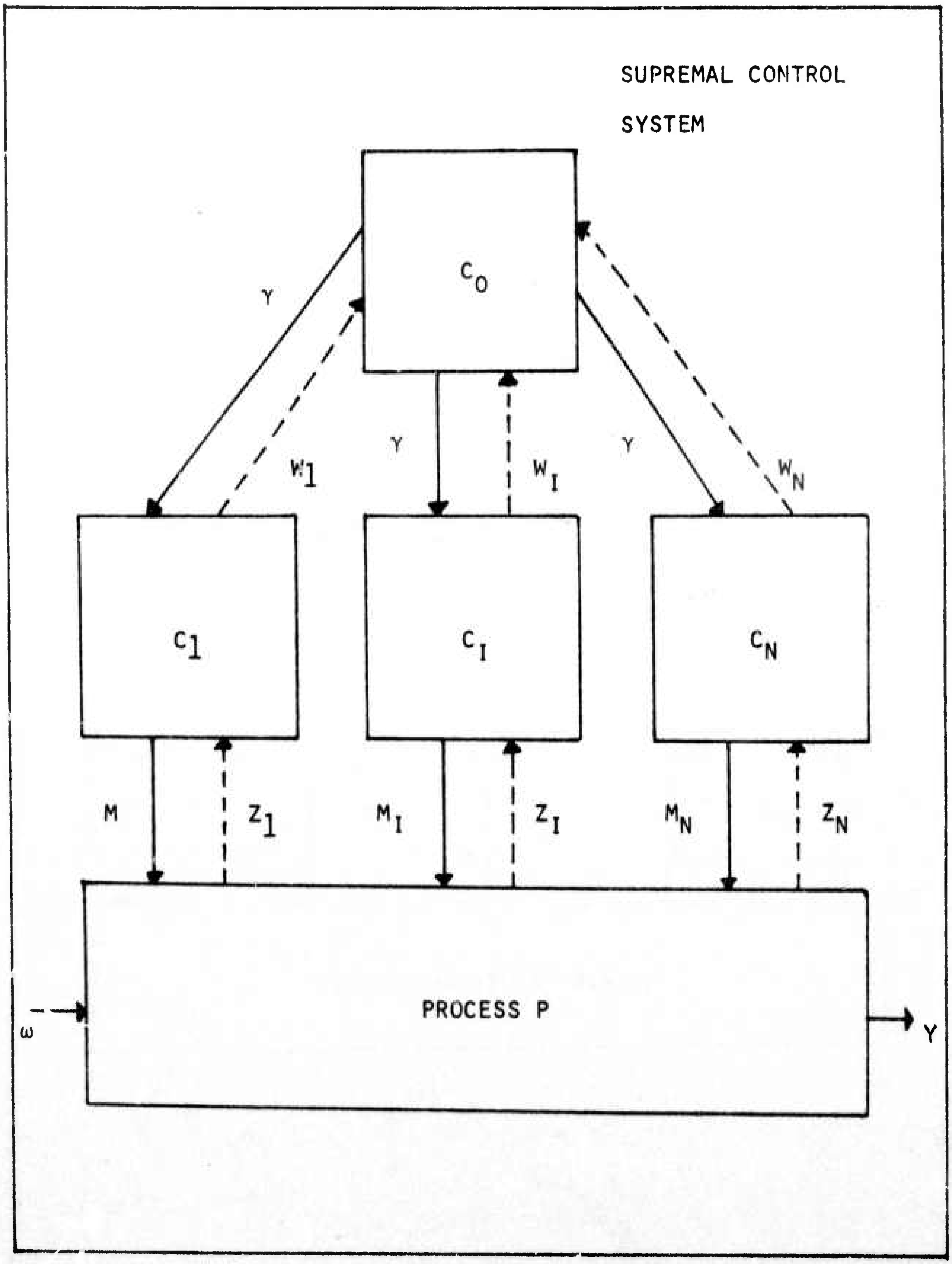


FIGURE II - A TWO-LEVEL SYSTEM WITH N INFIMAL CONTROL SYSTEMS AND A SINGLE SUPREMAL CONTROL SYSTEM*

*TAKEN FROM MESAROVIC, ET AL., 1971, P. 86.

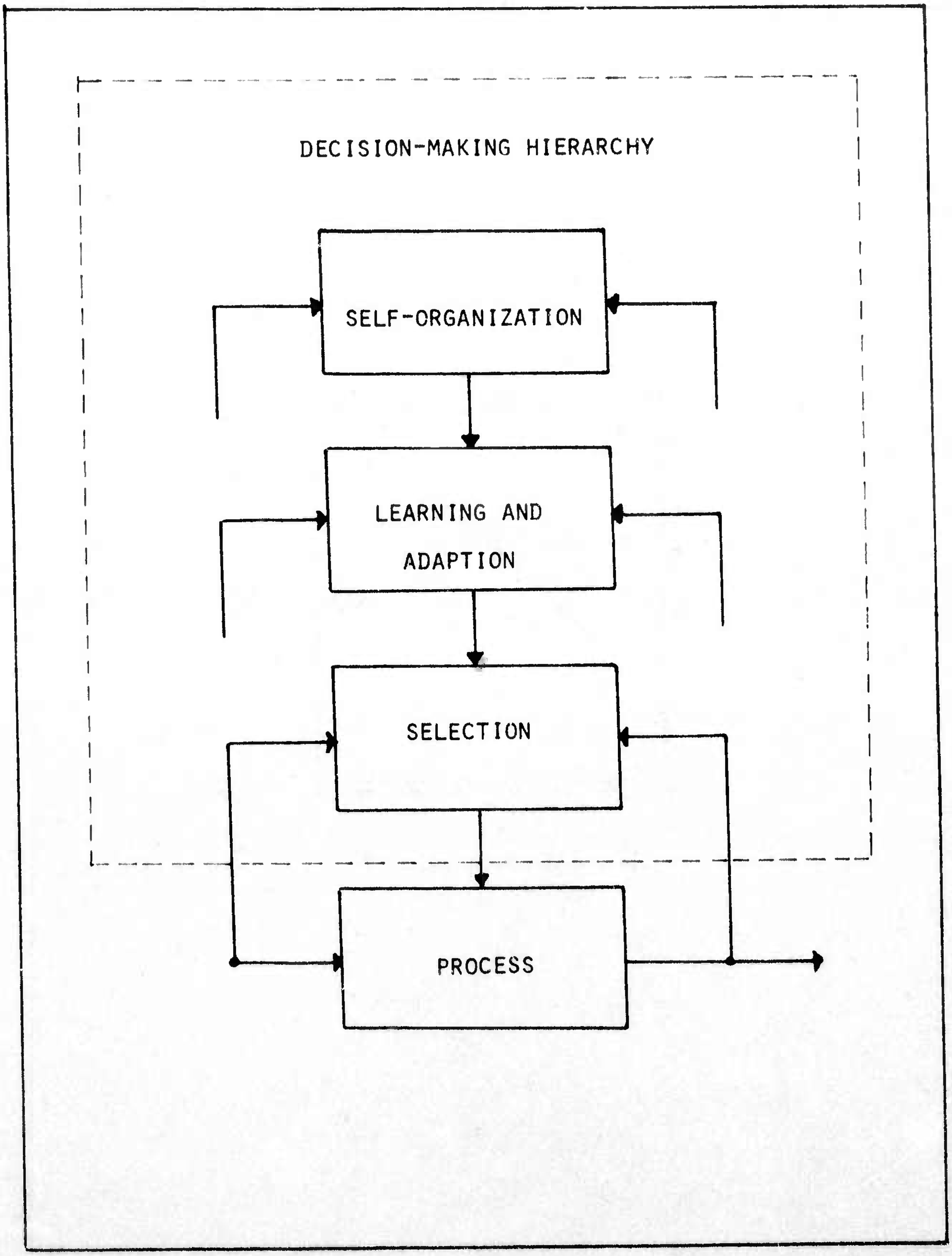


FIGURE III - FUNCTIONAL MULTILAYER DECISION HIERARCHY*

*TAKEN FROM MESAROVIC, ET AL., 1971, P. 47

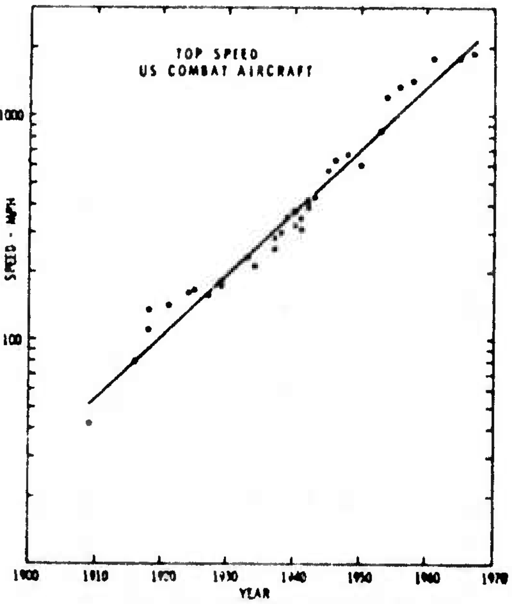


FIGURE IV - TOP SPEED OF U. S. COMBAT AIRCRAFT*

*TAKEN FROM MARTINO, 1972, P. 135.

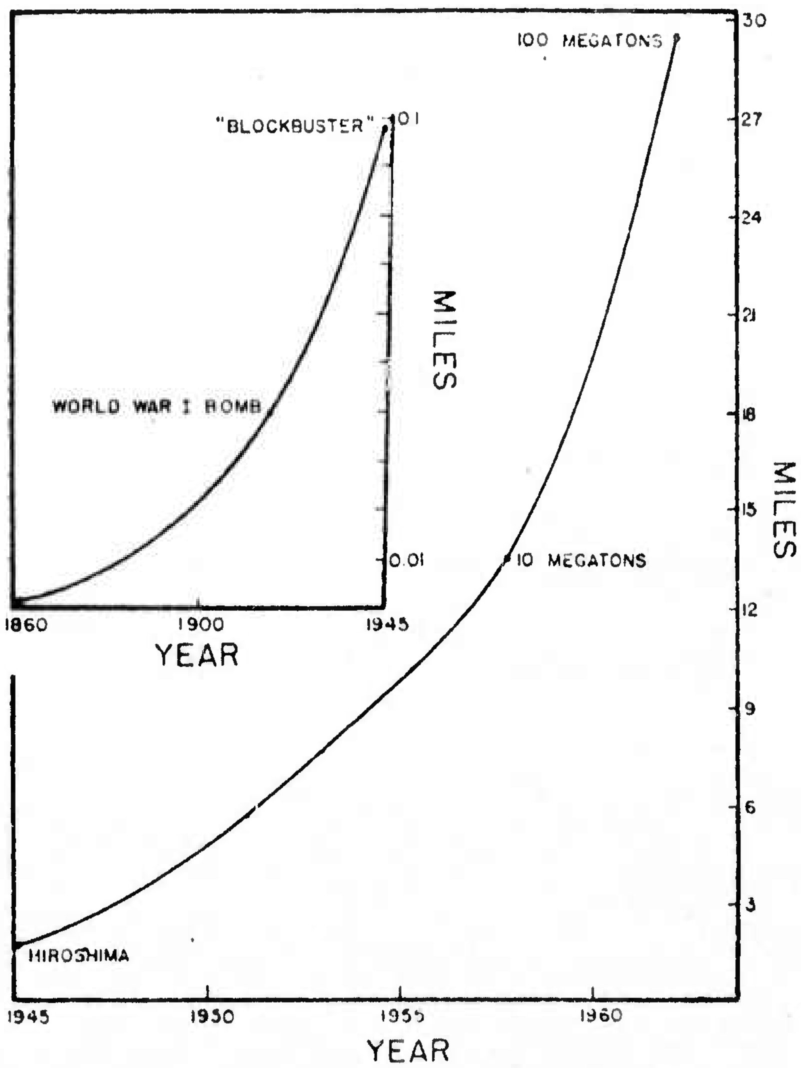


FIGURE V - MORE BANG FOR A BOMB: MAXIMUM DESTRUCTIVE RADIUS OF EXISTING WEAPONS, 1860-1960. (Calculated from U. S. Atomic Energy Commission, The Effects of Nuclear Weapons (Washington, 1962). Destructive radius defined as sufficient blast overpressure (3 pounds per square inch) to collapse an ordinary frame house.)*

*Taken from Russett, Trends in World Politics, 1968, p. 10.

	WHAT EFFORT?	WHAT SUCCESS?	WHAT ACTION?	FUTURE IMPLICATION?
PRESIDENT	H	L	L	H
SENIOR POLITICAL	M	H	H	H
WORKING LEVEL	L	M	H	L

FIGURE VI - APPLICABILITY OF FORECASTING PROBLEMS TO BUREAUCRATIC LEVELS

	WHAT EFFORT?	WHAT SUCCESS?	WHAT ACTION?	FUTURE IMPLICATION?
CONSENSUS TECHNIQUES	H	H	L	L
TREND EXTRAPOLATION	L	H	L	L
CORRELATIONAL FORECASTING	L	H	H	M
DYNAMIC CASUAL MODELS	L	M	H	H

FIGURE VII - APPLICABILITY OF FORECASTING TECHNIQUES TO FORECASTING PROBLEMS

Dynamic Foreign Policy Interactions

Warren R. Phillips
Department of Political Science
Ohio State University

July 1973
Project Research Paper No. 3

Prepared in connection with research supported by the Advanced Research Projects Agency, ARPA Order No. 2345-3D20, Contract No. DAHC 15 73 C 0197.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Project for Theoretical Politics The Ohio State University 053 Administration Building	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

"Dynamic Foreign Policy Interactions"

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Research Report # 3

5. AUTHOR(S) (First name, middle initial, last name)

Warren R. Phillips

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
July 30, 1973	25	45

8a. CONTRACT OR GRANT NO. DAHC15 73 C 0197 b. PROJECT NO. A.O. 2345-3D20 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) # 3 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited and production in whole or in part is permitted for any purpose of the United States Government.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Advanced Research Projects Agency Washington, D.C.

13. ABSTRACT

An approach to the study of the interactions of nations is developed in this paper based on the perspective that nations develop routines for dealing with each other, routines of reciprocity and bureaucratic inertia. More precisely, this approach seeks to specify how decision makers select types of action and reactions from an inventory of foreign policy outputs to meet different kinds of routine and non-routine international situations. The theoretical structure of this approach is laid out which essentially posits that the foreign policy output of a nation is a function of reciprocity and bureaucratic inertia. To differentiate the relative impact of each, the concept of uncertainty is introduced. Finally, it is acknowledged that nations are not all governed by theoretical restraints imposed on them through the parameters of inertia and reciprocity, that there are other forces at work both within these nations and within their environment which influence the impact of inertia and reciprocity. Several such forces are identified and briefly discussed (e.g. domestic events, and third party actions).

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Reciprocity						
Bureaucratic inertia						
Domestic events						
Third party actions						
Dynamic interactions						
Uncertainty						
Information						

STATEMENT OF PERSPECTIVE

The approach developed here is designed to increase our understanding of the way nations deal with each other. It is based upon the belief that the behavior of one nation towards another is a function of its previous experience in dealing with that nation. In short, it is the perspective of this approach that nations develop routines for dealing with each other, routines of reciprocity and inertia. Other forces which affect the exchanges between two nations do so in such a manner as to strengthen or weaken the effect of one or the other of these two routines.

In attempting to develop a greater degree of knowledge about the interaction of nations in the international system, we consciously strive towards an explanation of this interaction. What underlies this approach is a desire to specify how national decision-makers tend to select types of actions and reactions from an inventory of foreign policy outputs to meet different kinds of routine and non-routine international situations. Several basic assumptions underlie this approach.

a) The concept of foreign policy as a set of decisions by officials is adopted.
b) Foreign policy activity can be understood as consisting of discrete behaviors representing the outcomes of these decisions.
c) Policy can be interpreted as the aggregation of these behaviors according to some logic imposed upon them by the actor or the observer.
d) The behavior of one actor towards another actor (foreign policy) is responsive to the actions of other nations and involves efforts to influence who the leaders of these nations will be, what decisions they will take, and how they will define the relations between their nation and others.

e) Foreign policy is made in an environment by decision-makers who have mixed desires and domestic constraints to cope with. Their activity is essentially a process of adaptation to the external and internal environment which they seek to coordinate in an effort to maintain economy and sovereignty of the nation state.

On a still more abstract level it is argued that national decision-makers consciously choose policy which may affect the overall patterns of cooperation or conflict in the international system. This type of explanation generally assumes that there is at least one individual within the nation who understands the dynamics of cooperation and conflict in the system, who knows how other statesmen and his own constituents will react to a given policy, and who uses his knowledge to get around the constraints which reactions impose. This is the argument made by Stanley Hoffman (1968) in his delineation of roles in American foreign policy. This was also the type of argument made by William Langer (1931) in his discussion of the policies and motivations of Otto von Bismarck.

RELATION TO PREVIOUS WORK

One of the earliest advocates of the events approach to international interaction was Charles McClelland. He suggested that once the relations of international politics were broken down to their most elementary form they can be selected and organized according to two references--of actors and interaction. For McClelland, interaction analysis or demand response pattern analysis has as a preoccupation, tracing the resulting patterns and trajectories of actions.

He suggests that national systems have access to only a limited inventory of demands and responses in coping with the situations produced by system disturbances. How the government of the national system tends to select types of actions from the inventory to meet different kinds of non-routine international situations provides evidence of its operational code in international politics (1966:105).

Recently several theorists have underscored the importance of considering the total interactions, especially those between antagonists. Burton (1968) asserts that the progression towards war depends upon the equal contributions from both sides, each being governed by perceptions of threat. North and his colleagues assert that war may occur in a number of ways, but the chances of its occurrence are increased by the hostility in the crisis atmosphere generated by the joint exchanges of parties involved (1968). Zinnes has been concerned both with the expression of hostility and with its perception and the ensuing responses (1968). These authors all emphasize the process of exchange that underscores the symmetric importance of both participants and actions. Thus, the flow of foreign policy exchanges between nations has certainly been the topic of discussion, debate, and analysis. It has infrequently been the target of formal theoretical development, however.

While our current problems stem from a lack of formal explanation of the patterns and interactions between nations, it must be pointed out that the difficulty has not been because we have lacked a basis for making formal explanations. The possibility of using the international communications literature, (which is rich in suggestions

for formulating formal theories) has been made by a number of international relations scholars (Deutsch (1953), McClelland (1967), and Phillips (1973)). Quincy Wright (1955:269) defined international communications as the "art of using symbols to express, to inform, to formulate, or to influence the opinion and policy of groups on matters of importance for international relations. In a narrower sense it is the art of using symbols expressive of one nation to influence another. As a discipline it is the philosophy guiding that art and the science analyzing international communications, determining their purposes, and measuring thier effects." In fact, we can view the entire political process as a process of mutual modification of images through feedback in communication (Boulding, 1956:102).

Consider the simple communication system. Such a system has a message and three operating parts: a sender, a medium or channel and a receiver. There are several difficulties to be encountered in the process of communication, however. Does the receiver actually receive the message as the sender intended or does interference in the channel distort or garble the message? An excellent review of these problems can be found in Alan Whiting's (1969) discussion of the problems the United States faced in the bombing of North Vietnam. The United States had to convince the Chinese that its aircraft did not intend to cross the Chinese border. Whiting points out that many statements and subsequent actions were repeated to insure that the Chinese correctly understood the intentions of the United States. Such complex communications structures are a common feature of the international environment. Nation

states are information processors dealing with so much information that their information gathering powers are frequently taxed. How nations cope with this problem and to what degree these communications affect international relations is a crucial question in international relations according to Karl Deutsch (1968), who has hypothesized that wars are caused by the inability of decision-makers to handle message overload situations.

CONCEPTUAL SCHEME

To further develop this explanation of foreign policy outputs, consider the competitive international environment in which a nation operates. The behavior of one actor toward an object state is in part a response to the strategic problems which that actor faces with respect to its understanding of the other's goals and activities. It is not especially daring to suggest that behavior begets behavior, we simply expect that nations will generally act much like individuals, in the sense that there is a strong tendency to return behavior similar to that received. Nations are assumed to be operating not in a vacuum but in a real world in which inter-nation interaction is a reality. A nation, as an actor in the international system, will largely base the nature of its interaction with the second nation or object on the nature of the last or last several actions of that nation towards itself. By way of example, consider the work of Lewis Fry Richardson and his contention that the rate of change in hostility of one nation towards a second depends upon the level of hostility which the second harbors towards the first.[2] This idea of a relationship between the

actions of one nation and the past behavior of the object nation has been generalized by Dean Pruitt (1969) with the introduction of the concept of reciprocity. "The change in one party's level of output on a given dimension often produces reciprocity (also called reciprocal change) i.e., a resulting change in the other party's level of output on the same or another dimension."[3] These thoughts can be expressed in the following statement: an actor's behavior towards a specific object is a function of the behavior which it received from the object; more simply put, behavior begets behavior. Mathematically, this statement is represented by the following equation:

$$B_{nq,m,t} = \sum_{m=1}^{P} \alpha_m B_{qn,m,t}$$

where

$B_{nq,m,t}$
is the behavior of nation n directed toward nation q on dimension m at time t.

$\sum_{m=1}^{P} \alpha_m B_{qn,m,t}$
is the weighted sum of each of nation q's behaviors toward n as measured, respectively, along the P dimensions of behavior. The weights (α's) used in computing the sum are the relative importance of nation q's behavior, on each dimension, in influencing the behavior of nation n on dimensions m.

This equation states as a working hypothesis that an actor's behavior results from the patterns of action of its object. Others working in international relations, Tanter (1972), Azar (1970), and Leng (1972) suggest similar hypotheses.

This can be called a tit-for-tat model of the relations between nations. But international relations must certainly be more

than a tennis match in which each actor's response is to his object's service. There are forces at work over time within a nation which work to insure specific strategies be employed when dealing with specific object nations. Halperin suggests that "most of the actions taken by bureaucracies involve doing again or continuing to do what was done in the past. In the absence of some reason to change their behavior, organizations keep doing what they have been doing" (1970:9). Bureaucratic inertia, as an explanation of performance in organizations, is appealing and leads to the working hypothesis that a nation's behavior in foreign policy results, in part, from its own prior patterns of action. Stated formally: <u>a given nation's behavior toward a specific object is a function of its previous behavior toward that object</u>. Mathematically this can be translated into the linear equation:

$$B_{nq,m,t} = \alpha_m B_{nq,m,t-1}$$

where the symbolization is identical to the first equation and $t-1$ is a time period earlier. Combining the two approaches together to form a single equation:

$$B_{nq,m,t} = \alpha_m B_{nq,m,t-1} + \sum_{m=1}^{P} \alpha_m B_{nq,m,t}$$

The meaning of the individual terms remains the same as in the two preceding equations.

(1) The new equation expresses mathematically the contention that foreign policy dynamics are powerfully influenced by both bureaucratic inertia and reciprocity.

McClelland (1961) suggests that the workings of a modern foreign office resemble the day to day operations of a well run industrial plant. Following this suggestion we may develop the tit-for-tat models somewhat further. Multitudes of difficulties and problems would be received and dispatched from the daily flow by specialists in handling foreign affairs. To cope with this complexity, experts reassign responsibility for monitoring the exchanges with specific countries. The ability of the experts to deal with their assigned tasks is in part a function of their understanding of the intent underlying the patterns of behavior which were received from object nations in the recent past. In order to know the appropriate response to make to an object nation, the experts must be able to understand clearly and unambiguously the messages which they are receiving from the object. Halperin and Kanter suggest, "the nations affect the actions of one another less by physically compelling changes in behavior than by acting on one another's perceptions and expectations; interaction among nations is primarily a matter of threats, promises, and warnings designed to influence behavior by persuasion. Accordingly, the primary vehicle for the exercise of international influence takes the form of 'signals' among international actors. Actions--the outputs of the national security bureaucracy--are 'signals', designed to persuade another nation to alter its behavior in the preferred direction" (Halperin and Kanter, 1973:40).

Thus, the transmission and reception of information is a major feature of the behavioral exchanges between nations. Every act of a nation can be considered as a potential piece of information communi-

cating to other nations the intense desires or dislikes of the acting nation. In addition, the variety of behavior is itself, an important aspect of the information conveyed. If the multitude of international behaviors is structured into a basic set of patterns, the variety of international interaction can be shown to reduce to the knowledge gained from each of these patterns of behavior. If, for instance, the behavior of nations reduces to eight basic patterns, then there are eight areas in which information is being transmitted.

There are two procedures for delineating these basic patterns of interaction. The first technique would be to employ a large number of variables measuring interaction and to factor these variables to delineate a basic set of patterns or underlying dimensions (Phillips, 1969; McClelland and Hoggard, 1969). Another technique would be to specify a set of variables which are thought to be logically discrete and all inclusive. The second approach would have to specify the underlying rationale for such a collection of variables. The CREON data set has a group of variables which seem to meet the requirements for the second approach and it is accepted in this development. There are eight variables which indicate a continuum of commitment of resources on the part of the nation using them. These variables are laid out in Table 1. Notice that they vary from procedural discussions to military actions. It is felt that nations choosing foreign policy output from any one of these eight acts are signaling varying levels of commitment of natural resources from relatively minor commitments for procedural acts through relatively severe commitments for military actions.

The amount of information being conveyed between nations in any period of time must depend upon both the number of signals transmitted from nation to nation as well as the variety of signals. Techniques have been developed to measure and account for both the variety of signals transmitted and the amount of information transmitted. The heterogeneity of these signals--that is the variety of basic patterns at any point in time is a measure of the uncertainty which would attend any attempts to specify the sender's selection process (Cherry, 1957; Shannon and Weaver, 1949; Ashby, 1952).

Information theory provides an excellent measure of the uncertainty, H, present in a set of signals;

$$H = \sum_{i=1}^{N} - P_i \log_2 P_i$$

where P_i is the independent probability of the occurrence of signal type I and there are n types of signals. Thus, from the probabilities P_i of different types of signals occurring in a given time period (same month), the uncertainty associated with the score for that period can be ascertained. If all outputs are equally likely, uncertainty is at a maximum. It is common to divide the actual uncertainty by the maximum value, deriving as a result the percentage of (maximum) uncertainty (H_{rel}), which is more easily comparable across sources with differing sets of signals.

Let us consider two examples: first the case in which a particular nation chooses to send to a particular object 80 acts in a given time period. The distribution of these acts is such that each of the

eight variables are used ten times. Notice that the actor has chosen to send an equal number of each type of signal to the object. By way of contrast another nation sends the same object 80 acts in the same time period but they are all the same act. The relative uncertainty figure for the distribution in Example one would be 1.00, and that for the distribution in Example two would be 0.00. Thus, the implications of uncertainty are that in the equal probability instance, there is no way to judge if further occurrences would be more likely to fall in one category rather than another. In the second example, we can see that the object nation would be more likely to expect to receive the same act he has been receiving in the last eighty sequences. Thus an observer's uncertainty as to the likely activity of the actor represented in the second example is reduced. The smaller the H_{rel} figure, the more certain it is that a nation will choose a particular activity. McClelland has interpreted this relative uncertainty by suggesting: "A common sense way to view a series of H_{rel} numbers is to think in terms of a 'fanning out' toward equality of distribution across the category system with the larger figures and a channeling in of the distribution towards relatively frequent occurrences in fewer categories with the smaller figures. As the ratio approaches 1.00 it suggests not only that everything that could happen has been occurring but also that the behaviors have shown increasing signs of disorderliness. The information measures do not tell us what the particular lack of ordering is, but they do give us a technical indication of a large amount of variety in the emissions. As the

ratio decreases towards .000, the suggestion is that (1) there may be present a large amount of highly patterned and repetitive behavior and a limited variety in the action or (2) very little is occurring" (1973:91).

A long series of analyses by Charles McClelland and his associates (1965, 1968, 1973) have been carried out with the variety measure introduced above to establish how it functions in crisis and non-crisis periods. They have demonstrated that the mix of behavior does indeed change in a crisis towards greater variety. The basic results are these: (1) With occasional exceptions, a H_{rel} of .700 or higher is associated with crisis months and only with crisis months. (2) If we operationalize the beginning and duration of international crises with a H_{rel} of .700 or higher, we are able to state when a particular crisis began and how long it lasted. (3) All non-crisis periods, with rare exceptions, have monthly H_{rel} figures below .700 (McClelland, 1973:92-93). The literature on communications in international relations argues that in periods of crisis, system overload occurs and actors display an inability to respond consistently to foreign policy inputs (Holsti, 1965; Burton, 1968). This would suggest that for dyads in periods of high relative uncertainty, usually crises, nations are less able to respond consistently to their object nation's activities. But it seems to be the case that in periods less uncertain than crises, nations are capable of responding more reciprocally when they know more fully their opposite's interactions. This point needs further development.

Burton has suggested that one of the "tricks" in negotiation is that actors should send frequent responses if they wish to communicate changes in the perception of the situation. He also suggests that the process of resolution of conflict is in part a process of testing whether information is received as it was transmitted (Burton, 1969: 54-55). One function of ambiguity and noise in message signals sent from one nation or another, as pointed out by Jervis, is "to make it easier for actors to strike and maintain bargains. At first glance the contrary argument seems more plausible--that the easier it is for each side to make its views understood (at least on the semantic level), the more the bargaining process is facilitated--. . . this position might be correct if the actors could make the other side believe they would act the way they said they would" (1970:127). But since this is normally impossible, noiseless bargaining would make simple initiatives less plausible and thus more likely to be discounted.

In communications terminology noise is characteristic of a communication period with high relative uncertainty. Thus when nations are sending multiple types of signals it would appear easier for other nations to respond with what they judge to be appropriate behaviors. This is so because multiple types of signals allow a nation to test whether its intent was correctly received by analyzing the multiple responses. It is also likely to be the case that if one nation wants the other to believe its intent, it had better signal its intent in multiple ways or by orchestrating its signals.

Nations which are interacting frequently must consider how they can make other nations understand the intent of their communications. If a nation wishes to orchestrate its foreign policy outputs to facilitate understanding:

1) It must design and deliver messages in a way that will gain and hold the attention of the intended object.
2) The signals must adequately refer to past experience between actor and object.
3) The communicator must choose actions to match his verbal statements so that the message is convincing.
4) The communicator must be able to notice and interpret any responses as either feedback or as the performance of preferred behavior before he can estimate his degree of satisfaction measured against his country's objectives.[4]

Now let us interpret what we seem to be getting at in this discussion. When single signals ($H_{rel} = 0$) are sent, they are likely to receive only a moderately standard response. Slightly more complex messages (with a relative uncertainty value greater than zero but less than 0.5 for any given period) are somewhat more easily responded to in a systematic fashion. On the other hand, those messages which are quite heterogeneous in the number of signals sent (but short of the complexity facing crisis participants) can be responded to clearly and consistently.

This leads to the following assumption:

(2) Provided that the communications channel is not overloaded, the more heterogeneous the signals sent from one nation to another in a given time period, the more certain are observers in specifying an appropriate response.

Extrapolating from this discussion, let us suggest that when there is a homogeneous signaling from one nation to another (that is,

when the redundancy in signals is high) one would expect the recipient nation to identify less clearly the intent of the actor and to act on its own inertia. For periods of time in which there is a heterogeneity of signals (behaviors), and thus a richer mix of behavior for that time period, objects are more certain about the implications (real or potential) of the actor's behaviors. In these periods of time, reciprocity should exert a stronger influence than inertia upon foreign policy outputs. Hence, objects adjust to actors' strategies more readily in periods of high uncertainty and tend to continue doing what they had done in the past during periods of low uncertainty. Formally:

(3) In periods of high relative uncertainty reciprocity is a better predictor of foreign policy output of a nation than is inertia, while in periods of low uncertainty inertia is a stronger influence than is reciprocity.

What we have tried to accomplish here is a differentiation between when bureaucratic inertia on the one hand, and reciprocity on the other, tends to best explain foreign policy output. In order to facilitate this effort we have relied upon a new concept: uncertainty. The concept is given meaning in information theory and that meaning has been borrowed here. Three points are worth reiterating:

1) Information is assumed to be associated with a selection process. That is, there is available to the sender a choice of signals to be sent.
2) Such a process is basically statistical in the sense that it involves probability considerations concerning the likelihood that a given signal will be sent.
3) The amount of communication in the sense of transmission of knowledge (semantic information) is not considered in information theory.

Returning once again to the discussion of a well-run foreign office, we note that such an office is composed of country specialists who:

1) Monitor, categorize, sort and interpret incoming signals; and
2) Develop routines for converting the signals received into different information to serve specialized purposes.

Because of shared experiences in dealing with each other, an ordered pattern of understanding takes shape jointly for both the actor and the object. The information filters, in the form of these specialists which each nation relies upon become more adept at processing more and increasingly complex information and in responding in more heterogeneous patterns of behavior. This reasoning leads to:

(4) The development of complex patterns of interactive behavior is dependent upon relatively frequent and consistent exchanges in the past.

SPECIFIC ASSUMPTIONS AND HYPOTHESES

A specification of the completed system of statements about foreign policy outputs can now be given form:

Axiom 1 A given nation's behavior toward a specific object is a function of its past behavior from that object; more simply, behavior is a function of inertia and reciprocity.

Axiom 2 Provided that the communications channel is not overloaded, the more heterogeneous the signals sent from one nation to another in a given time period, the more certain are observers in specifying an appropriate response.

Theorem 1 In periods of high relative uncertainty reciprocity is a better predictor of foreign policy output of a nation than is inertia, while in periods of low uncertainty inertia is a stronger influence than is reciprocity.

Axiom 3 The development of complex patterns of interactive behavior is dependent upon relatively frequent and consistent exchanges in the past.

The CREON data collection comprises three months from each of the ten years 1959-1968. Since data are available for only one quarter from each year, our ability to test Theorem 1 is limited to testing the effect of signal heterogeneity upon reciprocity; any test of inertial effects would require contiguous data.

The propositions applicable to the CREON data set which we have been laboring toward may now be stated:

Proposition 1: Reciprocity will be lower in periods of low uncertainty than in periods of high uncertainty.

Proposition 2: The complexity in patterns of interactions will be greater in dyads which inhibit frequent exchanges than in dyads which interact only infrequently.

SUMMARY

At this point in the development of a theory of foreign policy exchanges, a self-contained explanation has been reached. But foreign policy exchanges should not be considered as a monotonous ballet in which all players are governed by identical restraints placed upon them through the parameters of inertia and reciprocity. It is to be argued here that a number of other forces are operating both within the nation and within the nation's environment which influence the degree to which a nation reciprocates behavior received or chooses to continue past behavior. These indirect forces which are at work in the decision-making process are not as yet, formally developed but likely candidates can be identified.

Certainly the pressure of domestic events would seem to act as an important instrument or force in influencing a nation to over or under respond to the receipt of behavior from other nations (Phillips,1973). During periods of intense domestic activity, key decision-makers must devote energies to solving or controlling the internal disruption to the degree that their time is consumed with domestic events, their ability to orchestrate foreign policy is minimized. Since this is the case, we would expect over and under responses to opponent's moves during these periods. One way in which domestic events and international situations may interact to create pressures upon the choice of routines being employed is by changing the level of decision-makers involved in a decision. In its simplest case we can divide decision-makers into two groups; working level bureaucrats and senior political offices away from foreign affairs. On the other hand, international crises ought to draw senior political offices into the decision process.

Third party actions are also considered to be influencing the action and reaction model that has been set out here. At the data collection level, Hermann and Salmore point out the need for considering the indirect object of a behavioral action (1970). Phillips and Hainline (1973) have studied the secondary impact of actions in the stimulus response models developed here of the triad--Soviet Union, United States, and China. Phillips and Callahan (1973) have attempted to formalize this position to account for the indirect efforts of third parties on the behavior of a dyad.

Perhaps the most important of a nation's basic functions is its ability for self-transformation "[t]o respond to events in its environment in new ways or at least in different and more rewarding ways" (Deutsch, 1968:17). Upon close investigation, Deutsch finds that there is a certain underlying similarity between the governing or self-governing of ships and machines and the governing of human organizations (such as foreign-policy-making organizations). "Steering a ship implies guiding the future behavior of the ship on the basis of information concerning the past performance and present position of this ship itself in relation to some external course, goal, or target. In such cases the next step in the behavior of the system must be guided in part by information concerning its own performance in the past" (1968:182). Deutsch proceeds to suggest that all self-steering networks have three basic elements: receptors, effectors, and feedback controls (1968:182). Whatever ability to act autonomously an organization such as a nation-state may have is in its feedback controls. Norbert Weiner defines these feedback controls:

> This control of a machine on the basis of its actual performance rather than its expected performance is known as feedback, and involves sensory members which are actuated by motor members and perform the function of telltales or monitors, that is, of elements which indicate a performance . . . (1950:12).

Deutsch develops the notion of steering based upon feedback in considerable detail. "Steering is always employed with reference to both a purpose, or goals, and an evaluation of previous successes and failures through the mechanism of feedback.

What has been attempted here is a rationale for looking at the exchanges between nations. It appears to be the case that nations attempt to achieve reciprocity in matching outputs to inputs. But this consistency is a function of their goals and the information, or feedback, they have of previous success and failure. What must follow is an attempt to expand upon these notions and to identify those forces which make the process a dynamic one with a good deal more fluctuations than simple matching routines would suggest.

FOOTNOTES

1. The author wishes to express gratitude to the Advanced Research Projects Agency (ARPA Order No. 2345-3D20, Contract No. DAHC15 73 C 0197, RF 3527-A1), the National Science Foundation (Grant No. GS-3117), the Mershon Center for Education in National Security, and to the Ohio State University Instruction and Research Computer Center for their support during the preparation of this paper. In addition, special thanks to Robert Crain for assistance on related papers.

2. "This theory is about general tendencies common to all nations; about how they resent defiance, how they suspect defense to be concealed aggression, and how they respond to imports by sending out exports; about how expenditure on armaments is restrained by the difficulty of paying for them; and lastly, about grievances and their queer irrational ways, so that a halting apology may be received as though it were an added insult." (Richardson, 1960:13).

3. Research in psychology tends to support the notion of reciprocity. Taylor (1965) and Tognoli (1967) provide evidence suggesting that increases in the intimacy of a subject are due to the increasing intimacy of his companion's remarks. Changes in the rate of smiling also tend to be reciprocated in the same time (Kendon, 1967). Explanation for the norm of reciprocity may be found in Gouldner (1960) and Pruitt (1965, 1968). Homans (1961) has attempted to explain reciprocity in terms of stimulus-response learning theory.

4. Goldman (1972:70) describes similar communication rules for domestic politics.

BIBLIOGRAPHY

ASHBY, W.R. (1952) *Introduction to Cybernetics.* New York: Barnes and Noble.

AZAR, E.A. (1970) "Profiling and Predicting Patterns of Internation Interactions: A Signal Accounting Model." Paper presented at the APSA Annual Meeting, Los Angeles, California (September).

BOULDING, K.E. (1956) *The Image.* The University of Michigan Press.

BURTON, J. (1968) *Conflict and Communication.* New York: Free Press.

--- (1969) *Systems, States, Diplomacy, and Rules.* Cambridge: Cambridge University Press.

CHERRY, C. (1957) *On Human Communication: An Inquiry into the Foundations of Nationality.* Massachusetts: MIT Press.

DEUTSCH, M. (1953) *Nationalism and Social Communications: An Inquiry into the Foundations of Nationality.* Massachusetts: MIT Press.

--- (1968) *The Analysis of International Relations.* Englewood Cliffs: Prentice Hall.

GOLDMAN, R. (1972) *Contemporary Perspectives on Politics.* Princeton: D. Van Nostrand Company.

GOULDNER, A.W. (1960) "The Norm of Reciprocity: A Preliminary Statement." *American Sociological Review,* XXV, pp. 161-178.

HALPERIN, M.N. (1970) *Bureaucratic Politics and Foreign Policy.* Washington: The Brookings Institution.

HALPERIN, M.N. AND A. KANTER (1973) *Readings in American Foreign Policy.* Boston: Little Brown.

HERMANN, C. AND S. SALMORE (1971) "The Recipients of Foreign Policy Events." The Ohio State University mimeo.

HOFFMAN, S. (1968) *The State of War.* New York: Praeger.

HOLSTI, O.R. (1965) "Perceptions of Time, Perceptions of Alternatives and Patterns of Communications as Factors in Crisis Decision-Making." *American Political Science Review,* LIX.

---, R.C. NORTH AND R. BRODY (1968) "Perception and Action in the 1914 Crisis," *in* J.D. Singer (Ed.) *Quantitative International Politics: Insights and Evidence.* New York: Free Press.

HOMANS, G.C. (1961) *Social Behavior: Its Elementary Forms*. New York: Harcourt, Brace and Co.

JERVIS, R. (1970) *The Logic of Images in International Relations*. Princeton: Princeton University Press.

KENDON, A. (1967) "Some Functions of Gaze-Direction in Social Interaction." *Acta Psychologica*. XVI, pp. 22-63.

LANGER, A. (1931) *European Alliance and Alignments*. New York: Knopf.

LENG, R. (1972) "Behavioral Indicators of War Proneness in Bilateral Conflict." A paper prepared for the 1972 APSA meeting, Washington Hilton Hotel, Washington D.C. (September 5-9).

MCCLELLAND, C.A. (1961) "The Acute International Crisis." *World Politics*. 14, pp. 182-204.

--- (1966) *Theory and the International System*. New York: MacMillan.

--- (1967) "International Communications," *in International Encyclopedia of the Social Sciences*. New York: MacMillen.

--- (1968) "Access to Berlin: The Quantity and Variety of Events," *in* J.D. Singer (Ed.) *Quantitative International Politics: Insights and Evidence*.

--- (1973) "The Beginning, Duration, and Abatement of International Crises: Comparisons in Two Conflict Arenas," *in* C.P. Hermann (Ed.) *International Crises*.

--- AND G.D. HOGGARD (1969) "Conflict Patterns in the Interactions Among Nations," *in* J.N. Rosenau (Ed.) *International Politics and Foreign Policy: A Reader in Research and Theory*. New York: Free Press.

---, *et al* (1965) "The Communist Chinese Performance in Crisis and Non-Crisis: Quantitative Studies of the Taiwan Straits Confrontation, 1950-1964," China Lake, California, U.S. Naval Ordnance Test Station NOTSTP 4138.

NORTH, *et al* (1968) See Holsti, North, and Brody, 1968.

PHILLIPS, W.R. (1969) "Dynamic Patterns of International Conflict." Ph.D. Dissertation and *Dimensionality of Nations Project Research Report #33*. University of Hawaii

--- (1973) "The Conflict Environment of Nations: A Study of Conflict Inputs to Nations in 1963." *In* J. Wilkenfeld (Ed.) *Conflict Behavior and Linkage Politics*. New York: McKay.

--- AND P. CALLAHAN (1973) "Dyanamic Foreign Policy Interactions: Some Implications for a Non-Dyadic World." Prepared for delivery at the 1973 meeting of the Midwest Political Science Association, Pick-Congress Hotel, Chicago, Ill. May 3-5.

--- AND M. HAINLINE (1973) "Major Power Conflict Exchanges in the Sixties: A Triadic Analysis of the Soviet, U.S. and Chinese Subsystem." Behavioral Sciences Laboratory mimeo.

PRUITT, D.G. (1965) "Defnition of the Situation as a Detminant of International Action," in H.C. Kelman (Ed.) *International Behavior: A Social-Psychological Analysis.* New York: Holt, Rinehart and Winston.

--- (1968) "Reciprocity and Credit Building in a Laboratory." *Journal of Personality and Social Psychology,* VIII, pp. 193-247.

--- (1969) "Stability and Sudden Change in Interpersonal and International Affairs," *in* J.N. Rosenau (Ed.) *International Politics and Foreign Policy: A Reader in Research and Theory.* New York: Free Press.

RICHARDSON, L.F. (1960) *Arms and Insecurity.* Pittsburgh: Boxwood Press.

SHANNON, C.E. AND W. WEAVER (1949) *The Mathematical Theory of Communication.* Urbana: University of Illinois Press.

TANTER, R. (1972) "International System and Foreign Policy Approaches: Implications for Conflict Modeling and Management," *World Politics,* XXIV, pp. 7-39.

TAYLOR, D.A. (1965) "Some Aspects of the Development of Interpersonal Relationships: Social Penetration Processes." University of Delaware, unpublished doctoral dissertation.

TOGNOLI, J.J. (1967) "Reciprocal Behavior in Interpersonal Information Exchange," University of Delaware, Unpublished doctoral dissertation.

WHITING, A. (1969) "How We Almost Went to War with China." *Look Magazine.* April 29, pp. 76-77.

WIENER, N. (1950) *The Human Use of Human Beings.* Boston: Houghton Mifflin.

WRIGHT, Q. (1955) *The Study of International Relations.* New York: Appleton-Century-Crofts.

ZINNES, D. (1968) "The Expression and Perception of Hostility in Prewar Crisis: 1914," *in* J.D. Singer (Ed.) *Quantitative International Politics: Insights and Evidence.* New York: Free Press.

TABLE 1

Eight Behavioral Variables Used

The eight behavior types (behavioral variables) used in this study are derived from the Sequential Action Scheme of the CREON codebook.

	Variable Number and Name	Definition
b_1	PARTICIPATION	All "Procedural" statements
b_2	DIPLOMATIC EXCHANGE	All "Evaluative" except "Procedural" statements
b_3	VERBAL COOPERATION	All "Desire" and "Intent" except "Procedural" which are seen as "Desired" or "Neutral" by Actor
b_4	VERBAL CONFLICT-DEFENSIVE	All "Elicited" "Desire" and "Intent" except "Procedural" seen as "Undesired" by Actor
b_5	VERBAL CONFLICT-OFFENSIVE	All "Unelicited" "Desire" and "Intent" except "Procedural" seen as "Undesired" by Actor
b_6	COOPERATIVE ACTION	All "Deeds" seen as "Desired" by Actor
b_7	NON-MILITARY CONFLICT ACTION	"Symbolic" and "Significant" "Deeds" seen as "Undesired" by Actor
b_8	MILITARY CONFLICT ACTION	"Military" "Deeds" seen as "Undesired" by Actor

Dynamic Foreign Policy Interactions: Some Implications for a Non-Dyadic World

Warren R. Phillips
Project for Theoretical Politics
Ohio State University

and

Pat Callahan
Department of Political Science
Ohio State University

May 1973
Project Research Paper No. 4

The authors wish to express their gratitude to the Advanced Research Projects Agency, ARPA Order No. 2345-3D20, Contract No. DAHC 15 73 C 01977, RF 3527-A1, the National Science Foundation (Grant No. GS-3117), the Mershon Center for Education in National Security, and to the Ohio State University Instruction and Research Computer Center for their support during the preparation of this paper. Of course the responsibility for any errors contained here, whether of commission or omission, lies solely with the authors.

Prepared for delivery at the 1973 meeting of the Midwest Political Science Association, Pick-Congress Hotel, Chicago, Ill. May 3-5.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

Project for Theoretical Politics
The Ohio State University
053 Administration Building

2a. REPORT SECURITY CLASSIFICATION

UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

"Dynamic Foreign Policy Interactions: Some Implications for a Non-Dyadic World"

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Research Report #4

5. AUTHOR(S) (First name, middle initial, last name)

Warren R. Phillips
Patrick T. Callahan

6. REPORT DATE

July 30, 1973

7a. TOTAL NO OF PAGES

53

7b. NO OF REFS

28

8a. CONTRACT OR GRANT NO

DAHC15 73 C 0197

b. PROJECT NO

A.O. 2345-3D20

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

4

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited and production in whole or in part is permitted for any purpose of the United States Government

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

Advanced Research Projects Agency
Washington, D.C.

13. ABSTRACT

In this paper the attempt is made to develop a more formal theoretical approach to the study of the effects of third parties on the dyadic interactions of nations. A fully formalized general theory is presented and some of the predictions which it generates are tested. Particular attention is paid to the impact of saliency on the shaping of an actor's foreign policy in the context of dyadic and triadic consistency considerations. The findings reveal that third party activity does have an impact on dyadic relationships and that its impact is generally conditioned by the saliency of the third party to the actor involved. Thus, both third party activity and saliency are shown to be important considerations in the attempt to specify the decision making rules which nations use in dealing with other nations. Moreover, this paper demonstrates the utility of developing formal models to achieve this end in the context of the growing difficulties associated with the application of statistical methods to such endeavors.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Reciprocity						
Saliency						
Third parties						
Strategies						

UNCLASSIFIED
Security Classification

This paper is part of a continuing effort to produce a general theory of foreign policy activity. We hope to increase our understanding of foreign policy decisions by being able to explain the pattern of interactions between nations. We assume that the interactions between two nations are embedded in a larger environment consisting of other nations and the interactions among them. In this paper the effort will be advanced by articulating a fully formalized general theory, giving it an interpretation and testing some of the predictions which it generates.

The essential building block of our theory is the interaction paradigm. This approach to international politics has a long and venerable tradition in the literature. Its baptism into scientific literature was initiated by Charles McClelland. He suggested that once the relations that make up international politics were broken down into their most elementary form they take on the basic pattern of figure 1. It shows that the facts of international relations can be selected and organized according to the two references of actors and interactions (McClelland, 1966, p. 18). Other theorists have underscored the importance of considering the total interactions in a dyad when explaining foreign policy behavior, especially when the nations comprising the dyad are antagonistic (Burton, 1968; North, et. al., 1968; Zinnes, 1968). This literature suggests that the behavior of one nation acting towards another (the object) is in large part dependent on the behavior of the object to the actor. It is not especially daring to suggest that

behavior begets behavior. We simply expect that nations will generally act much like individuals in the sense that there is a strong tendency to return behaviors similar to those received. Nations are assumed not to be acting in a vacuum but in a real world in which interaction is a reality. A nation, as an actor in the nation-state system, will largely base the nature of its interaction with the second nation (object) on the nature of the last or last several actions of that object nation toward the actor. Tests of these concerns (Phillips, 1971, 1972) have tended to provide support for this assertion. Other works in international relations (Tanter, 1972; Bartos, 1966; Azar, 1970) suggest similar hypotheses.

But international politics must surely be more than a tennis match in which each actor's response is to the object's service. The outer environment of the nation contains many nations, the behavior of each having potential implications for the capacity of the decision-makers of the nation to devise policy which can achieve national goals. These third parties have an impact on the interactions of the dyadic pair both by creating contradictions in policy actions and by diverting the attention of decision-makers from the pattern of interactions in the dyad. For instance, the fact that two nations are engaged in armed conflict will narrow the range of alternatives of other nations who choose to interact with either of the conflicting parties. An ally of the nation which is attacked feels pressure to punish the aggressor, both by increasing the conflict the agressor experiences and by decreasing the cooperation it receives.

An analysis of the interactions among the United States, the Soviet Union and the People's Republic of China has shown clear empirical justification for the belief that third parties have an impact on dyadic interaction patterns (Phillips and Hainline, 1972). It was found there that Chinese actions towards the United States or the Soviet Union were quite sensitive to the exchanges between the United States and the Soviet Union. This paper will attempt to go beyond that effort to develop a theory of the effect of third parties upon dyadic interactions.

In order to build our theory we have found it necessary to make the following four assumptions:

1. Foreign policy can be conceptualized as a series of decisions made by national officials. Foreign policy activity consists of discrete behaviors representing the outcome of these decisions.

2. Foreign policy can be operationalized as the aggregation of the foreign policy activity (behaviors) according to some logic imposed upon them by the actor or observer.

3. The behavior of one actor towards another (foreign policy) is responsive to the actions of other nations and involves efforts to influence who will be the leaders of those nations, what decisions they will make, and how they will define the relations between their nation and others.

4. Foreign policy is made in a multination environment by decision-makers who have to cope with domestic constraints and who have mixed desires. Their activity is essentially a process of adaptation to the external and internal environment which they seek to coordinate in an effort to maintain autonomy and national sovereignty while pursuing positive goals in the international system.

These assumptions require that our theory begin with some decision-making premises and that when it comes to the

interfacing of theory and data that the data represent highly disaggregated measures of behavior so that the logic of decision can be examined empirically. Therefore, we use international events data as our data base.

We turn now to the problem of building the theory. The first step is to specify the language in which the theory can be embedded. The language we have chosen to use consists of a vocabulary of four elements; three variables and one operation defined on those variables, and a grammar, namely, vector algebra.

The first element in the vocabulary is a variable. It is a set of entities active in international politics. We call this set Y. Formally, this can be represented as[1]

$$Y = \{ y_1, y_2, y_3 \ldots . y_n \}$$

where each y_i represents a discrete entity in the international system. In our development we shall confine our attention to those entities which are nation-states. The analysis could perhaps fruitfully be extended to include international organizations of both the intergovernmental and nongovernmental varieties and multinational corporations.

The second element in the vocabulary is also a variable. It is a set of categories of behavior which may be directed from one member of Y to another. We call this set A. Formally

$$A = \{a_1, a_2, a_3, \ldots, a_m\}$$

Examples of such sets are quite important in the international relations literature. Each set is a categorization scheme allowing one to measure foreign policy output. One example of such a

set would be the dichotomy between the cooperation and conflict. Another would be the 63 categories in the World Event/Interaction Scheme devised by McClelland.

The third element in the vocabulary is a set of time periods. We shall call this variable T. This variable can be stated formally

$$T = \{t, \ t+1, \ t+2, \ . \ . \ . \ , \ t+q\}$$

In this research we shall assume that each element in T is a fairly long period of time, and that the time is measured in clock time.[2] An implication of this assumption is that time is constant across all terms in most of our equations. Therefore, in the equations the time subscript has not been explicitly stated but has been assumed to be equal on all terms in the equations. In those few equations where it is not possible to assume the same time for all terms the time subscripts have been explicitly provided.

In addition, it should be noted that if shorter periods of time were employed in building the theory or if some conception of social time were employed to measure time (for example, the number of days since a nation y_i was the target of action from some other nation y_j), then the formulation of the theory would be drastically different. Time subscripts would have to be explicitly stated for all terms for all equations, and the language of the theory would have to be some dynamic system such as differential or difference equations. Therefore, the choice of time measurement is crucial and should be kept in mind in evaluating the theory.

Employing these three elements, we can define a three dimensional space. The space is the product set of the elements of Y times the elements of Y times the elements of A at any time t, where in one case the elements in Y are taken to be the initiators of action and in the other case are the recipients of action. We call this space X. Formally,

Definition 1: $X = Y \times Y \times A$

An example of this space is illustrated in figure 2. The dimensions of the space are as follows:

length = n columns representing the n elements in Y in their capacities as actors

height = n rows representing the n elements in Y in their capacities as targets

width = m columns representing the m categories of behavior in A

The fourth element in the vocabulary is an operation which sums the number of discrete instances of behavior category a_k in A directed toward any entity y_j in Y by any other entity y_i in Y. This operation fills the cells in X with integers.

We can now use this information to defi · a set of concepts which we will need in developing the theory. The first of these can be stated formally as:

Definition 2: $x_{ijk} = \{x: x \in X, x = y_i \times y_j \times a_k\}$

In other words, Definition 2 states that x_{ijk} represents the behavior of entity i to entity j in behavior category k. As an example, the idea of the threatening behavior of the U. A. R. toward Israel would be an interpretation of this abstract concept.

The formal statement of the second of these concepts is:

Definition 3: $\langle x_{ij} \rangle = \{x_{ij1}, x_{ij2}, \ldots, x_{ijm}\}$

In English this definition states that the vector x_{ij} represents the behavior of entity i to entity j in all behavior categories of A. An example of a substantive interpretation of this idea would be the U. A. R.'s foreign policy behavior toward Israel in a given time period.

The last of the concepts to be introduced here can be stated formally as follows:

Definition 4: $X_i = \{\langle x_{i1} \rangle, \langle x_{i2} \rangle, \ldots, \langle x_{in} \rangle\}$

Put another way, X_i is a matrix created by the set of vectors defined in Definition 3 above. The matrix has n rows and m columns defined by the n targets and m behavior categories respectively which a nation can choose in initiating a foreign policy act. This matrix is synonomous with the idea expressed in such phrases as the "foreign policy of Egypt". It should be noted in passing that the space X has an interpretation in the language of traditional political science writings. It is the

international system.

We turn now to the discussion of the substantive implications of characterizing the international system and foreign policy in this way. Operating from a decision-making perspective, we posit the following axiom and its corollaries:

Axiom 1: The foreign policy behavior of a nation y_i is the result of conscious decisions made by the decision makers in y_i.

Corollary 1.1: The nature of x_{ijk} is the result of conscious decisions made by the decision-makers of y_i.

Corollary 1.2: The nature of x_{ij} is the result of conscious decisions made by the decision-makers of y_i.

Corollary 1.2: The nature of x_i is the result of conscious decisions made by the decision-makers of y_i

This is a fairly noncontroversial set of statements about the nature of foreign policy. The second axiom to be introduced is not so uncontroversial. It draws on an intuition related to one of the initial assumptions stated in the first part of the paper, that foreign policy is a goal-seeking activity. If this is so then one would expect decision-makers to control the stream

of outputs so that actions do not mitigate against the effects of other actions. This can be stated formally in the following axiom:

> Axiom 2: The decision-makers in y_i seek to coordinate policy such that no x_{ijk} contradicts any other x_{ijk+1} in $\langle x_{ij} \rangle$ and each $\langle x_{ij} \rangle$ with each other $\langle x_{ij+1} \rangle$ in x_i so that there are no contradictions.

Note that this axiom does not say that the decision-makers are successful in this coordination effort. Indeed, it may be the case that many contradictions exist. In fact, one of the main thrusts of this paper is that it is impossible to avoid contradictions. But this does not deny the a priori validity of this axiom. It merely states that in the real world with multiple complexities, inadequate communications, memory failures and limited attention spans on the part of decision-makers, it is the tendency of decision-makers to avoid contradictions when they are able to discover them.

In order to make this pair of assertions falsifiable and therefore scientific, we must first make more explicit the sorts of decision-rules we expect decision-makers to follow in formulating foreign policy. And before this can be done we find it necessary to provide more information concerning the nature of the elements in the set A of categories of foreign policy behavior. Our strategy in this will be to define two

subsets of behaviors in A, cooperation and conflict. We will then posit a mathematical function which will reduce all the information in x_{ij} to two scalars, one of which measures the amount of cooperation and the other the amount of conflict. We will then provide a means for examining the balance of cooperation and conflict in a dyad and move from there to the concept of dyadic inconsistency. This concept will give us a handle on analyzing the nature of coherence and contradiction in foreign policy, which is where we want to get right now.

One of the basic distinctions in the analysis of foreign policy is that between cooperative and conflictual behaviors. We propose to employ the same distinction. Cooperation is understood to be those behaviors which are desired by and, therefore, rewarding to the target. Conflict is understood to be those behaviors which are undesired by and, therefore, punishing to the target. These distinctions can be introduced formally into the theory by means of the following definition:

Definition 5: $A = C \; F$

where $C \; A$, $F \; A$

C is the subset of behaviors which can be identified as cooperative

F is the subset of behaviors which can be identified as conflictual

$\phi = C \; F$

In other words, cooperation and conflict make up mutually exclusive and exhaustive subsets of the set of behaviors A

Because of this definition we must make a series of necessary changes in the notation used to identify the dyadic behavior of a nation. The next definition provides these changes.

Definition 6: $<x_{ij}> = <c_{ij}> \cup <f_{ij}>$ where

$$<c_{ij}> = \{<x_{ij1}, \ldots, x_{ijk}> : x_k \in C\}$$

$$<f_{ij}> = \{<x_{ijk+1}, \ldots, x_{ijm}> : x_m \in F\}$$

Or, cooperation and conflict are mutually exclusive and exhaustive subsets of the behavior of nation y_i to nation y_j, that is, $<x_{ij}>$.

Given this information it is possible to posit the existence of a function on each subset which will reduce the information in each to a scalar (a single number). Axiom 3 provides us with that.

Axiom 3: $C^{*}_{ij} = <\gamma_{ij}>_{1 \times k} <c_{ij}>'_{k \times 1}$

$$F^{*}_{ij} = <\lambda_{ij}>_{1 \times k} <f_{ij}>'_{k \times 1}$$

What this axiom says is that we take the inner product of a vector of behaviors and a set of weights,

This linear operation has the effect of creating a weighted scale to measure conflict or cooperation, by reducing the vectors to scalars. (For a simple explanation of the mathematics involved in these operations, see Davis, 1965, pp. 32-38.) Notice, too, the substantive implications introduced. The vectors of weights, γ and λ, provide the perceptual grids by which national decision makers evaluate foreign policy behaviors. The fact that each vector is subscripted with both the actor and the object, e.g., C_{ij}, indicates that we are not imposing a requirement for a uniform

grid for all nations in all dyadic situations. Rather, we allow each set of decision-makers to bring a different perceptual grid to each dyadic relationship.

Now we would like to further reduce the information about the behaviors in x_{ij}. We would like to combine for each directed dyad the values of C^*_{ij} and F^*_{ij} so that a single value will result. We want the function that does this to provide us with an interval scale measurement. If it does this, it will tell us the balance of cooperation and conflict in a dyad as perceived by the actor nation. We believe the following function meets these criteria.

Axiom 4: $X^*_{ij} = C^*_{ij} - F^*_{ij}$

The preceding exposition has been made the way that it has for the purposes of substantive clarity. Within the grammar of matrix algebra the same result can be achieved in a much simpler manner. This would be to make super matrices of γ and λ on the one side and C_{ij} and F_{ij} on the other. By creating a super-matrix is meant that one vector is hooked onto the end of the other, creating a new vector. We now do this, making one additional necessary assumption.

Axiom 4^*: $X^*_{ij} = \langle\pi_{ij}\rangle_{1xm} \cdot \langle R_{ij}\rangle'_{mx1}$

where π_{ij} = a supermatrix created by the concatenation of $\langle\gamma_{ij}\rangle$ and $\langle\lambda_{ij}\rangle$

R_{ij} = a supermatrix created by the concatenation of $\langle c_{ij}\rangle$ and $\langle f_{ij}\rangle$ and all the elements in $\langle\lambda_{ij}\rangle$ are assumed to have a negative value, that is, to provide a negative weight.

This assumption means that the perceived affect of any conflictual act is in the opposite direction as that of any cooperative act.

Note that through the operation stipulated in Definition 4* the original space X has been reduced from an n x n x m space to an n x n square matrix.

We are now nearly to the point at which some interesting things can be said about foreign policy within the language structure which we have created. The only preliminary step which remains is to define another concept, that being the degree of dyadic consistency or inconsistency. This is taken care of in the following definition.

Definition 7: A dyad is said to be strongly inconsistent if $(A^*_{ij}, \overrightarrow{A}^*_{ji})$ or if $(\overrightarrow{A}^*_{ij}, A^*_{ji})$.

a dyad is said to be weakly inconsistent if (A^*_{ij}, A^*_{ji}) and $A^*_{ij} \neq A^*_{ji}$ or if $(\overrightarrow{A}^*_{ij}, \overrightarrow{A}^*_{ji})$ and $\overrightarrow{A}^*_{ij} \neq \overrightarrow{A}^*_{ij}$.

A dyad is said to be consistent if and only if $A^*_{ij} = A^*_{ji}$ or $\overrightarrow{A}^*_{ij} = \overrightarrow{A}^*_{ji}$

In the preceding definition A^*_{ij} means that the balance in the ij dyad is predominantly cooperative, and $\overrightarrow{A}^*_{ij}$ means that the balance is predominantly conflictual.

We can now further specify the nature of the conscious choices made by national decision-makers, as postulated in Axiom 1 and Corollaries 1.1 and 1.2 (the exploration of 1.3 will be delayed until later in the paper). The reciprocity approach to international interactions suggests an appropriate starting place. Decision makers seek to eliminate strong inconsistencies in their

dyad relationships and to minimize the weak ones. In other words, decision makers strive for consistency in interaction patterns. This rule can be stated in the axiom:

> Axiom 5: The decision makers in nation y_i choose foreign policy actions according to the following rule: $\min (A^*_{ij} - A^*_{ji})$

Applying Axiom 4 to Axiom 5 we get Theorem 1:

> Theorem 1: Decision makers in nation y_i choose foreign policy actions according to the rule:
>
> $$\min \ (C^*_{ij} - F^*_{ij}) - (C^*_{ji} - F^*_{ji})$$

And by applying Axiom 3 to Theorem 1 we can get Theorem 2.

> Theorem 2: Decision makers in nation y_i choose foreign policy actions according to the rule: min
>
> $$\{[(\langle\gamma_{ij}\rangle \cdot \langle C_{ij}\rangle) - (\langle\lambda_{ij}\rangle \cdot \langle F_{ij}\rangle)] - [(\langle\gamma_{ij}\rangle \cdot \langle C_{ji}\rangle) - (\langle\lambda_{ij}\rangle \cdot \langle F_{ji}\rangle)]\}$$

And by applying Axiom 4^* to Axiom 5 we get the much more manageable statement of the substance of Theorem 2.

> Theorem 3: Decision makers in nation y_i choose foreign policy actions according to the rule:
>
> $$\min \pi_{ij}R_{ij} - \pi_{ij}S_{ji}$$
>
> where S_{ji} indicates the behavior input to nation y_i from nation y_j.

At its limit Theorem 3 reduces to

$$0 = \pi_{ij}R_{ij} - \pi_{ij}S_{ji}$$

Or

$$\pi_{ij}R_{ij} = \pi_{ij}S_{ji}$$

What the theorem implies is that nations are attempting to match

foreign policy outputs to inputs. The matching is done with respect to the perceived importance of conflictual and cooperative acts and varies from actor to actor for each object nation.

The other implication of the Theorem derives from the fact that we have one equation with more than one unknown (indeed, the number of unknowns is unknown, since it can vary with the number of behavior categories which one chooses to employ). The system of equations is therefore undetermined and indeterminate. There is an infinity of possible solutions. To indicate the kind of problem this is, a nation could reduce the inconsistency created by a more conflictual partner by either increasing its own conflict output or by leaving the conflict output constant and decreasing its cooperative output, or by adopting some hybrid of these strategies. What this means is that we cannot proport to be able to predict what kind of strategy a set of decision makers will adopt in order to meet the rule. We can only predict that they will adopt some strategy which will enable them to meet the requirements of the rule.

What has been developed above would not be an unreasonable place to stop if one were studying a simple two-nation international system. However, the system within which foreign policy decisions are made contains many nations. It seems fruitful, then, to go on and look for the implications of such a multimember system for the general validity of Theorem 3. We shall begin by looking at triadic interactions. A triad shall be considered as a set of six directed dyads composed of three entities such that each entity is the actor in two directed dyads and the target in two. This can be

formally posited as follows:

Definition 9: A triad $Tr_{hij} = \langle x_{ij}\rangle \cap \langle x_{ji}\rangle \cap \langle x_{ih}\rangle \cap \langle x_{hi}\rangle$
$\cap \langle x_{jh}\rangle \cap \langle x_{hj}\rangle$

An illustration of a triad is presented in figure 3.

Once again we have too much information to be handled effectively, so we wish to reduce it. We therefore call on the analytic steps carried out before in Definition 5 and Axioms 3 and 4 to modify definition 9.

Definition 9^{*}: A triad $Tr_{hij} = A^{*}_{ij} \cap A^{*}_{ji} \cap A^{*}_{ih} \cap A^{*}_{hi} \cap$
$A^{*}_{jh} \cap A^{*}_{hj}$

This definition gives us a triad defined by six scalars, two each for each pair of entities. We wish to reduce it further, and therefore modify the definition as follows:

Definition 9^{**}: A triad $Tr_{hij} = B_{ij} \cap B_{ih} \cap B_{hj}$

where $B_{ij} = \min (A^{*}_{ij}, A^{*}_{ji})$

$B_{ih} = \min (A^{*}_{ih}, A^{*}_{hi})$

$B_{hj} = \min (A^{*}_{hj}, A^{*}_{jh})$

In other words, the symmetric dyadic interactions can be represented as equal to the most conflictual directed dyadic link if at least one of these links is conflictual or as the least cooperative if neither is on balance conflictual.

We are now nearly in a position to make some statements of a substantive nature concerning the impact of triads on dyadic interactions. But before this can be done we must define a concept, triadic consistency. Before that can be done we need to introduce some additional notation. The next two definitions carry out both these tasks.

Definition 10: We shall refer to B_{ij} as B'_{ij} if and only if neither of the dyadic links is on balance conflictual, that is, if (A^{*}_{ij}, A^{*}_{ji}). We shall refer to B_{ij} as $\bar{B}'_{ij}$ if there is at least one directed dyadic link which is on balance conflictual, that is, if $(\bar{A}^{*}_{ij}, A^{*}_{ji})$ or $(A^{*}_{ij}, \bar{A}^{*}_{ji})$ or $(\bar{A}^{*}_{ij}, \bar{A}^{*}_{ji})$

So what we have done above is to reduce the information about the pair of dyads in each symmetric dyad in a triad to a dichotomy.

Definition 11: A triad may be said to be strongly inconsistent if and only if there are one or three $\bar{B}'_{ij}$ links. A triad may be said to be consistent if and only if $B_{ij} = B_{ih} = B_{jh}$. All other cases are said to be weakly inconsistent.

However, this definition does not meet the needs which we have. Rather, we need a functional definition which will produce an interval scale measure of the degree of triadic inconsistency. Furthermore, we want the function to rank order different inconsistencies, both weak and strong, and to weight the strong more heavily than the weak inconsistencies. The function must also produce a value of zero when the triad is consistent. Formally, we posit

Definition 12: $I_{hij} = f(B_{ij}, B_{ih}, B_{jh})$

We are not able to state at this time the nature of this function. Clearly it will be a complex mathematical operation. The job of discovering it will remain for future research efforts.

We turn now to the problem of assessing the impact of triadic inconsistency on foreign policy. As stated in the introduction, it seems to us that triadic patterns would have a significant impact on decision-making. The reason is that the actions of third parties can have a significant impact on the capacity of a nation to achieve its goals in relation to a target in a dyad. Clearly the actions of the Soviet Union and China have a tremendous potential for breaking the Vietnam policy of President Nixon, and this explains in some sense why it is that he pays so much attention to their actions in reference to Vietnam. This sort of relationship is posited to be a factor in foreign policy making.

Axiom 6: National decision-makers perceive third party behavior as a relevant factor in the achievement of policy goals.

How, then, is this perceived policy relevance translated into behavior. This is not ground untread by previous observers. Harary (1961) presented the concept of balance in a system. That concept was isomorphic with our concept of consistency in a triad. In reference to unbalanced systems (i.e., strongly inconsistent triads), he argued that the behavior of nations would change to bring the system back into balance. The reason for this was the rule that a friend of my friend is my friend, a friend of my enemy is my enemy, an enemy of my enemy is my friend, and an enemy

of my friend is my enemy. This seems plausible and we wish to have such a position in our theory. But we also want to exploit the characteristics of weakly inconsistent triads, because we feel that they also have an impact on the behavior pattern in a dyad. As an illustrative example, the United States periodically pressures the West European nations to contribute more in development assistance for the underdeveloped nations of the world. These cases could be interpreted as an instance of the United States attempting to reduce triadic inconsistency created by the undercooperation of the West European nations. We therefore posit the following relationship:

Axiom 7: National decision-makers choose foreign policy acts to reduce triadic inconsistency.

So far we have presented a language for talking about dyadic patterns of interaction and some composition rules for talking about triadic patterns of behavior. So far, however, in analyzing the rules of behavior at each level we have ignored the rules operative in the other level. We shall now attempt to fill that void by looking at the interaction between the rules of dyadic behavior. This is done in the following four theorems.

Theorem 4: It is possible to have all consistent dyads in an inconsistent triad.

Theorem 5: It is possible to have all inconsistent dyads in a consistent triad.

Theorem 6: It is possible to reduce dyadic inconsistency without affecting triadic inconsistency.

Theorem 7: It is not possible for a nation to choose actions which will reduce triadic inconsistency

without having some effect on

dyadic inconsistency.

No attempt will be made to prove Theorems 4-6 at this time since they are not germane to the latter part of the paper. A proof of Theorem 7 will be provided, however, since this is the theorem which generates our prediction of an impact of third parties on dyadic relations.

The proof consists of a demonstration that no valid counter-example can exist. Suppose that a nation y_i had foreign policy outputs at time t such that $(A^*_{ij})_t$. Assume that $(A^*_{ij})_t$ was more conflictual than $(A^*_{ji})_t$. Suppose that this generated dyadic inconsistency $U_t = (A^*_{ij})_t - (A^*_{ji})_t$ and triadic inconsistency $(I_{hij})_t = V_t$. Assume that all other relevant nations maintain the same behavior outputs from time t to time t+1. Assume further that γ_{ij} and λ_{ij} can change only very slowly over time and therefore are effectively constant over two time periods. The problem is, given these conditions, is it possible to get the result $V_t \neq V_{t+1}$ and $U_t = U_{t+1}$?

If $V_t \neq V_{t+1}$, then it must be the case, by definition 12, that $[f(B_{ij})_t, (B_{ih})_t, (B_{jh})_t] \neq [f(B_{ij})_t, (B_{ih})_t, (B_{jh})_t]$. By definition 9^{**} and by assumption we can deduce that $(B_{ih})_t = (B_{ih})_{t+1}$ and $(B_{jh})_t = (B_{jh})_{t+1}$. Therefore, to get $V_t \neq V_{t+1}$ it must be the case that $(B_{ij})_t \neq (B_{ij})_{t+1}$. Since by assumption $(A^*_{ji})_t = (A^*_{ji})_{t+1}$ it must be the case that $(A^*_{ij})_t \neq (A^*_{ij})_{t+1}$ for $(B_{ij})_t = (B_{ij})_{t+1}$ to attain.

If $U_t = U_{t+1}$ and $(A^*_{ji})_t = (A^*_{ji})_{t+1}$, then it follows that $(A^*_{ij})_t = (A^*_{ij})_{t+1}$.

Then to set up a counterexample one would have to show some case where both $(A^*_{ij})_t = (A^*_{ij})_{t+1}$ and $(A^*_{ij})_t \neq (A^*_{ij})_{t+1}$ obtained. This would require either $(A^*_{ij})_t \neq (A^*_{ij})_t$ or $(A^*_{ij})_{t+1} \neq (A^*_{ij})_{t+1}$. Since these are absurd results no counterexample can exist and Theorem 7 is proved.

The implication of this theorem is that it is possible and perhaps quite likely that nations must choose between actions which will enhance dyadic consistency but harm triadic consistency, or vice versa, and failure to act, thus harming dyadic consistency and enhancing triadic consistency, or vice versa. The problem then is to provide a rule by which the solution to this dilemma can be predicted.

We begin to attack this problem by defining the concept of saliency. Saliency is to be a measure of the importance of an entity to another entity. Thus saliency is an attribute of an entity in a relationship; that is, y_i is salient to y_j, for example. The concept of saliency is created to exemplify the historical importance of an entity y_i to y_j's foreign policy. The presumption is that the higher the saliency of an entity to an actor the more will that actor's foreign policy be shaped so as to exert control over the attainment of goals involving that object nation. We now formally define saliency and posit its impact on the interactions of dyadic and triadic consistency considerations.

Definition 13: Saliency of a nation y_j to y_i is a function of the amount of across-time interactions y_j has had with y_i, or

$$P_{ji} = [f\ (\sum_{t=1}^{1} \langle x_{ij}\rangle\ t)]$$

Axiom 8: The saliency of an entity for a nation determines the policy relevance of that entity for the nation.

We can now posit the completed theory in a single theorem:

Theorem 8: $x_{ij} = f'(\pi_i R_{ij} - \pi_i S_{ji}) + \varepsilon P_h I_a$

where f minimizes the value of the right side hand of the equation, I_a is the inconsistency of a triad a where both y_i and y_j are members of the triad, and P_h is saliency of the third party in the triad I_a

What has been presented above is a most general theory. As stated, it is incapable of supporting empirical matter. Before that can be done, the functions need to be defined and the key variables operationalized. Then the specific formulation of the theory can be tested and accepted or rejected. We turn now to fulfilling that job.

The Creon data source provides ample opportunity for operationalizing our concepts. That collection consists of information collected on the exchanges (foreign policy events) between 35 nations. The time frame is 1959 to 1968. Three month quarters (three consecutive months) were sampled at random from each of the 10 years. This provides ten, three contiguous month data subsets or 30 months of non contiguous data. This data enables us to create the Y x Y x X data cube. The Y x Y matrix will have rows and columns equal to the number

of nations in the international system at any point in time. From this we choose subsets of actors and objects for analysis. The behaviors along the A mode will be represented by an eight variable characterization of behavior. These variables begin with participation and progress along a continuum of increasing commitment of resources with the eight variable being military conflict. Table I presents the variable list.

The problem now becomes representing theorem 3:

$$\text{Min} \left(\pi_i R_{ij} - \pi_i S_{ji} \right) \qquad (1)$$

or

$$\text{Min} \left(\pi_j R_{ji} - \pi_j S_{ij} \right). \qquad (2)$$

Now set both (1) and (2) equal to zero:

$$0 = \pi_i R_{ij} - \pi_i S_{ji}$$

$$0 = \pi_j R_{ji} - \pi_j S_{ij}.$$

Now we have simultaneous equations for Y_i to Y_j and Y_j to Y_i behavior. It is argued that both nations attempt to match inputs to outputs in terms of their interpretation of inputs and outputs. In order to solve for the equation we need to make an assumption: Each nation perceives the other's behavior in the same way. This means.

$$\pi_i S_{ji} = \pi_j S_{ij}$$

This is a simple extension of the mirror image phenomenon. There it is agreed that each nation sees its own actions as good and both interpret the other's actions as bad (Stagner (1967) Bronfenbrenner (1961). Thus nation, i, places the same

interpretation on j's behavior as j places on his behavior. From this assumption it is easy to show that

$$\pi_i R_{ij} = \pi_j R_{ji}$$

Setting R_{ij} and R_{ji} in matrix form to represent repeated variable observations of behavior we have two ma 'xes each 30 months by eight behavioral variables. When we do this we have

$$R_{N \times M} \pi_{M \times M} = R^*_{N \times M} \pi^*_{M \times M} \text{ and}$$

Where $R\pi = A^*$ and $R^*\pi^* = A^*_{ji}$

A^*_{ij} and A^*_{ji} are now matrices. In other words there are multiple behavioral strategies which occur over time for each nation's dyadic relationships. Placing restrictions upon A^*_{ij} and A^*_{ji}

$$\{A_{ijk} A_{jig} = \begin{matrix} k_{kg}, & k=g \\ 0, & k \neq g \end{matrix}\}$$

$$A_{ijk} A_{ijk} = A_{jik} A_{jik} = 1 \text{ and}$$

$$A_{ijk} A_{ijg} = A_{jik} A_{jig} = 0, \ k \neq g.$$

These restrictions are synonymous with assumptions in the canonical model and allow its application. The research question now becomes, can we find patterns in both matrices of behavior that are highly correlated? When canonical analysis is employed with these two matrices, it delineates linear combinations from both matrices $\pi_i R_{ij}$ and $\pi_j R_{ji}$, such that the patterns are maximally correlated. At the same time each matched (or correlated pair) are uncorrelated with any other sets delineated in either matrix. The coefficients, π, are interpretable as the evaluation weights each side places upon events they send to the object in

order to minimize the difference between input and output. They can be interpreted both as a preference to respond to certain combinations of events received with specific combinations of events or as the underlying perceptual attempt to reciprocate in kind.

Findings

In analyzing this set of assumptions four nations were chosen: The Soviet Union, the United States, the Chinese Peoples Republic, and Japan. These four nations form twelve dyads. Six canonical analyses were performed, one for each of the linkages:

USR - USA

USR - CPR

USR - JPN

USA - CPR

USA - JPN

CPR - JPN

Tables II through VII present the results. The trace correlation delineates the general overlap between the matrices of behavior sent from each side of the dyad. In general these point out a good deal of overlap. The range of the traces is from .43 for USR - JPN interactions to .67 for USR- CPR exchanges. The reciprocity phenomena explains from 18 to 45 percent of the total relationships in these twelve dyads. There are sub sets of exchanges in each linked pair of dyads which are indicative of much stronger linkages. These subsets of exchanges are inter-related as high as .96 or a reciprocity in

overtime variations of behavioral exchanges of 92 percent. It is worth reviewing some of these linkages. In Chinese-Soviet relations it appears that the Soviets prefer to respond to Chinese offensive verbal conflict with verbal conflict but to keep this activity independent of other exchanges. Both parties seem to recognize a need for a strategy of neutral maintenance of relations which is independent of other strategies. This point is highlighted in the second variate pair. The third variate pair points to the suggestion that the Soviet Union is likely to introduce verbal conflict into procedural matrices but that the Chinese are quite sensitive to conflict mixed with procedural concerns. This would suggest that the CPR wants to isolate the verbal tirades so frequently assumed to be a characteristic of Chinese foreign policy from evidently quite meaningful attempts at negotiation. It also points to the possibility that in the Sino-Soviet relations it is the Chinese which recognize this fact more than the Soviets.

Turning to the US-Chinese relationships it appears that this dyadic exchange also highlights the independence of procedural activities of diplomacy and participation from the more evaluative kinds of actions. The first variate shows that US diplomatic activity towards the Chinese is reciprocated by procedural responses. On the other hand, independent of pattern maintenance activities US cooperative initiatives towards the Chinese tend to be rejected by the Chinese while US verbal

conflictual activities seem primarily to be ignored on the part of the Chinese. Thus, while it would appear that the Chinese are willing to reciprocate on procedural and diplomatic matters, they are unwilling to demonstrate cooperative reciprocity at this stage in US Chinese relations. On the other hand, they choose to ignore or to respond in non-routine fashions to US accusations and complaints rather than to reciprocate in kind or in a way which might escalate the conflictual initiatives on the part of the United States. It may be worth pointing out an interesting difference between Sino-Soviet and Sino-US exchanges. In the Sino-Soviet case, both sides hurl accusations and denouncements at each other while in the case of US-Chinese relationships, China seems to play the part of an unresponsive sparring partner and a unwilling lover.

Chinese relations with the Japanese point to a mixing of cooperation and conflict. The second variate suggests that the Chinese combine verbal cooperation with cooperative actions while at the same time rattling the sabre by using non-military conflict sanctions. The Japanese response is to highlight verbal conflict but to intermix verbal cooperative statements as well. This points to an inability to differenciate between conflict and cooperation strategies in the relations between the Japanese and the Chinese. When the Japanese choose overtly cooperative acts the Chinese do not respond in any reciprocal manner. These complex patterns may well indicate that Sino-

Japanese relations are embedded with a mixture of competition and comraderie. Certainly philosophical discussions of each others role in Asia would lay credence to this suggestion. If, however, the Japanese cooperative activity becomes too severe the Chinese back off by choosing not to make a clear response.

Soviet US relations are the most complex of those dealt with in this paper. There appears to be an independent procedural dimension which points to the agreements on both sides to cooperate in pattern maintenance activities independent of their conflicts of interest. In addition to this, however, diplomatic exchanges appear to be infused with a good deal of cooperation as both the Soviets and the United States tend to engage in verbal and cooperative acts during negotiations. During these periods it appears that the United States is more likely to apply the carrot and the stick by using verbal threats and accusations as well as promises and rewards while the Soviets tend to be less likely to infuse this strategy with conflictual verbage. Some diplomatic activity on the part of the Soviets is not reciprocated by the U.S. as pointed out in the third variate pair. On the other hand, the fourth variate may be the most interesting. It tends to suggest that as the United States increases its non-military conflict activity towards the Soviet Union, the Soviets increase their cooperative actions toward the United States and when the United States decreases its non-military conflict sanctions aimed at the Soviets, the

Soviets increase verbal conflictual activity. This would seem to be a deterrent strategy in which as the United States becomes more menacing the Soviets back off, and as the US becomes less menacing the Soviets tend to increase their threatening stances.

Japanese - US relations seem to be identified by cooperative reciprocity. There are, however, some interesting differences in strategy between the US and the Japanese. When cooperative acts are used by the United States they are reciprocated in kind by the Japanese. On the other hand, the Japanese respond with verbal cooperation to US procedural initiatives, but they do not choose cooperative actions in response to our procedural activities. This would suggest that the Japanese use cooperative talk much more freely than other nations but they are equally careful in the use of cooperative actions. On the other hand, in diplomatic bargaining with the United States they are not adverse to using verbal conflict, a strategy which the United States tends to shy away from in their dealings with the Japanese. What this seems to add up to is that when the United States is seriously acting cooperatively to the Japanese, the Japanese respond in kind. When the United States wants to talk about future activities, the Japanese are willing to signal verbal intentions but are not willing to commit themselves to cooperative acts unless the United States is willing to act. If the United States negotiations signal more commitment than their procedural matters, the Japanese will negotiate but they will not refrain from disagreeing with US positions.

Japanese - Soviet relations are quite simple. Cooperative acts on the part of either nation are reciprocated in kind with the Japanese evaluating slightly higher in this cooperative activity. When the Soviets threaten military activity, the Japanese scream. If the Japanese back off, the Soviets tend to reduce the level of conflictual actions. It would appear that the Soviets have a hard line strategy against the Japanese and that, while the Japanese do not like it, they are unwilling or unable to do more than protest.

These analyses point to a good deal of reciprocity in the relations between the four major nations analyzed here. This reciprocity appears to be quite complex. Nations evaluation of their own strategy and other strategies are definitely not simple act for act weighings. The sophistication of both the Chinese in separating verbal tirades from procedural and diplomatic exchanges and the Japanese in appearing to be willing to cooperate, but measuring the use of their cooperative actions carefully shows that there are a number of strategies for reciprocity in this system. This suggests that our minimization axiom is probably correct under the assumptions of the mirror image but the choice of actions used to respond to an object nation are indeed heavily dependent on situational factors. We would argue that consistent evaluation of behavior may be misleading. These results suggest that various acts are evaluated quite differently depending upon the object nation's mix of behaviors.

Turning now to analysis of the triadic impact on these exchanges, canonical analysis presents residual scores for the over

and under response in each of the patterns delineated in Tables II through VII. These residuals can be employed in an examination of the impact of third parties. If the third parties have an effect on the dyadic relations delineated here, then the residuals should be explained by behavior of third nations. Theorem 8 suggests that saliency is an important consideration in the impact of third party actions on dyadic exchanges. We have dichotomized the saliency coefficient into a zero/one case. All third parties are salient if they had exchanges with the actor in ten out of the thirty months in the CREON data. Thus, for each actor, in the twelve dyads delineated by using four major nations - the Soviet Union, the United States, China, and Japan - we have divided all nations in the CREON data deck into salient or non-salient subsets. In the case of the United States to China there would be thirty-three other nations in the sample. Any of those nations which had had more than ten months of exchanges with the United States were placed in the salient to US subset. Any of those nations which had had less than ten months of exchanges with the United States were placed in the non-salient to US subset. Then the residual matrix from the US - Chinese exchanges was compared with the salient and non-salient to the US behavior matrices. In order to do this, for each month all salient third party behavior to the United States was summed to form a single variable. All US behavior to those nations was summed to form a second behavior variable. A

third behavior variable was formed by summing all behaviors from salient to US third parties to the Chinese. And the final variable was formed by aggregating all Chinese behavior to third parties salient to the United States. This provides us with a matrix of four variables and thirty time periods in which the aggregated behavior to and from third parties on the part of both the actor and the object in the reciprocity analysis is formed. This matrix and the residual matrix are then analyzed in canonical analysis and the trace is presented in Table VIII.

Our theoretical development would suggest that the traces in the salient actors should be higher than the traces in the non-salient cases. This appears to be the case in all dyads in which the Chinese were not involved, with one exception. It would appear that nations which do not frequently exchange behaviors with the Chinese are indeed salient in Chinese relations with any of the three other major nations used here in the direct interaction Thus, the Chinese do weigh as more salient than our measure of salience would tend to suggest third party activities with whom the Chinese interact infrequently. We would suggest that it is likely to be the case that these third parties are developing nations from the third world and that China's relations with other major nations are more sensitive to these exchanges than is the case for other dyadic relationships amongst other major nations. We do not feel that this negates the theory, but rather suggests that our operationalization of salience needs to be redefined. All the traces suggest that third party activity does have an

impact upon dyadic relationships. And this impact must be analyzed more carefully in the future.

In performing this analysis, we began by attempting to lay out our theoretical concerns quite formally. Speaking personally, both authors can attest to the difficult but rewarding nature of specifying relations in a formal sense. We have found this exercise to be an extremely enlightening one. It has led us to question the utility of current statistical procedures in testing some of the substantively exciting theoretical explanations of foreign policy currently in vogue in the research literature. This work has been an attempt to specify the decision-making rules which nations use in dealing with each other on a daily basis. It grows out of research that the senior author began at the University of Hawaii and has continued at Ohio State in connection with the CREON Project and other data sources. What we are about to discuss in terms of shortcomings of analysis in this area certainly apply to previous works of the senior author but they also are found in other's research. There has been quite a lot of analysis attempting to delineate the foreign policy of nations (McClelland, 1961, 1967, 1968; Smoker 1968; Holsti, Brody and North, 1968; Zinnes, 1968; Tanter, 1972; Azar, 1970 Phillips, 1972, Phillips and Crane, 1972). All of these analyses have used aggregations of event or event type data. The problem also arises in those works that have attempted to relate domestic and foreign conflict (Wilkenfeld, 1968; Rummel, 1966; Tanter, 1963).

The problem stems from the fact that the underlying theoretical argument assumes a time frame considerably shorter than the data analysis time frame. This means that theoretical fluctuations are suspected to be occuring more frequently than the time unit in the data aggregated for analysis. Were this difference in aggregation levels to have arisen in aggregations such as cities, states, or countries, we would have been quick to recognize the dangers of an ecological fallacy It is only infrequently recognized that the ecological fallacy also applies to differences in aggregation of time (Orcutt, Watts and Black, 1968.).

While our analysis here demonstrates that the suggestion of the minimizing differences in behavior under the assumption of the mirror image has not been disproven an infinite number of other strategies for aggregating to the month-time frame could have just as equally produced the monthly aggregations that we have used. We want to make it clear that the substantive findings are not in danger but the explanation for these findings is not clearly supported. More importantly, perhaps even if minimization strategies can be demonstrated to be wrong independently of this analysis, the statistical techniques employed upon aggregations at the monthly period may well demonstrate a statistically acceptable answer. Consider, for instance, two nations, one sending a conflictual act to the other each of the thirty days in a month. The object nation responds only on the 29th day with 30 conflictual

actions. Were this to happen on a number of monthly occasions, there would be a strong correlation over the months analyzed. Yet this seems quite unacceptable as the object nation is not attempting to minimize its behavior. It is ignoring it and then in one swoop giving back everything that it received.

These problems stem from our aggregations. We have used months in this analysis, but more frequently we notice yearly analyses. These latter, we would suggest suffer more seriously when it is shorter time frame fluctuations of the nature suggested here upon which theoretical explanations are based. Since these fluctuations have not been identified, it is impossible to know whether aggregation in longer time frames created the relationship identified or indeed the hypothesized relationship occurs at all in the shorter time frames.

While we have known this problem for some time, it was in dealing with the triadic problem that this issue became more salient for us. How were we to handle third nations? Obviously our theory suggests that when a nation acts, it looks at who had acted recently, decides how salient their actions are for this relationship and chooses either to ignore or to be influenced by third partied activities. But, we had thirty-three other nations for each actor in our system. We began by wanting to use all thirty five nations dyadically but this would have created 33 x 35 or 1155 canonical analyses and and we knew that this was simply too much analysis. Therefore we limited our direct dyadic relationships to the four

nations or twelve dyads we employed. But, in order to develop a meaningful third party matrix we were forced to aggregate all third nations into two sets by assuming a zero/one measure of saliency. This implied that all nations' action in the third party matrix were simply lumped together once they were identified as being salient or unsalient to the actor in question. Had we used all eight forms of behavior, we would have had eight times four or thirty-two variables and a considerable over-identification problem. Attempting to get around that problem left us with no other choice than the aggregation that we developed. More importantly, however, the monthly aggregation of data meant that if three dyads exchanged behavior in a pattern similar to that in figure 2 we would assume that two actions A to C, and B to C were important in predicting A to B's behavior. But since A to C, and B to C's behavior came after A to B's behavior it is a logically absurd assumption.

Having gone through elaborate analytic and methodological gyrations it might seem bizarre to call into question what has been done by ourselves and others frequently in the past. Yet this paper is a good example of a growing difficulty in the application of statistical techniques to the study of foreign policy dynamics. The strength of this study may be summarized briefly: a more formal theoretical approach to a substantively well acknowledged problem ; how do nations choose foreign policy actions to cope with other nations?

The problems may be easily statea, as well, due to data constraints, an operational inability to identify concepts. We think this problem has eluded detection because too much emphasis has been placed upon difficulties in data collection and in mistakes found in the application of statistical techniques. We do not want to belittle the difficulties in data collection procedures, but we must point out that disagreements in this area can only be answered by resorting to measurement assumptions embedded in a formal theory (Phillips, 1972). Unfortunately, there are,as yet, too few formal theories for final assessment of most of these problems. As to arguments about the appropriateness of various statistical procedures, much of this debate, when not highlighting errors in technique, is also premature. In complex social systems such as foreign policy dynamics, the structure of a theory cannot in general be derived from statistical analysis of time series data (Brunner (1971), Thorson (1972), Hibbs (1972)). The key is to have a theoretical structure and specified relationships which properly represent that structure <u>before</u> considering analysis! We feel we have accomplished this requirement before we turned to data analysis. But now we fi-' that analysis lacking in some important respects.

The solution is painful, but obvious. We must disaggregate. Unfortunately the sparcity of data for shorter time frames in any of the data collections in the events movement

as well as most national accounts data sets is such that we may find ourselves unable to use normal statistical techniques when our theories seek to explain short run fluctuations. We at Ohio State believe that there is a need for developing formal models which seek to explain foreign policy dynamics. We valued immensely the exercise which attempted to lay out explicitly our expectations. We valued it not just because it led us to a deeper understanding of the hazards in analysis but it also has suggested a solution--all computer simulations. Such simulations would produce expected relations delineated in the front of this paper. Upon experimentation with different parameters and adding some randomness to the model, simulations could be developed in such a way to produce exchanges between simulate nations which could be compared with the underlying distribution of actions in the international system.

Perhaps a final argument is worth making. The analysis that we have been performing to date on these data sources has been primarily linear. This has produced expectations of constant responses to behavioral situations in the environment or domestic constraints at home. Thus, once the strategy or relationship is identified, it is assumed to be constant over time. To be sure, many of us have suggested that we would

have to continue analysis on other time frames to ascertain whether these parameters changed, but little published evidence is available that attmpets to specify the nature of the change or dynamics in parameters over time is developing. A simulation model can quite easily build adaptation routines into the axioms themselves.[3] Then we can begin to place the simulation under various stressing conditions to see whether it reacts in acceptable patterns.

We are not attempting to cast doubt on the whole of quantitative studies in international relations. We are, however, warning that too frequently we attempt to develop explanations which we test on data aggregated at the yearly or decade level and that in many instances this data simply does not allow us to reach conclusions about the accuracy of our explanations. Solutions to these problems are more easily identified as we begin to develop a generation of formal theoretical systems. The more frequently we see this form of formalization the more easily the difficulties of the nature posed here can be brought to light and solutions developed to deal with the problems.

Figure 1: The International System

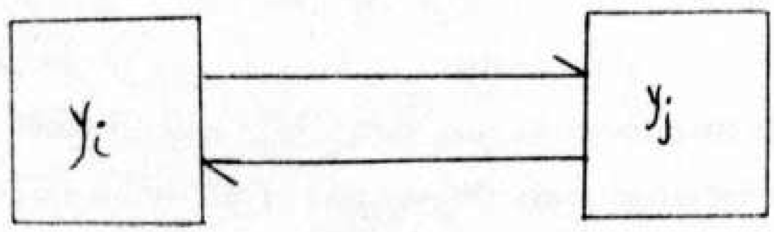


Figure 2

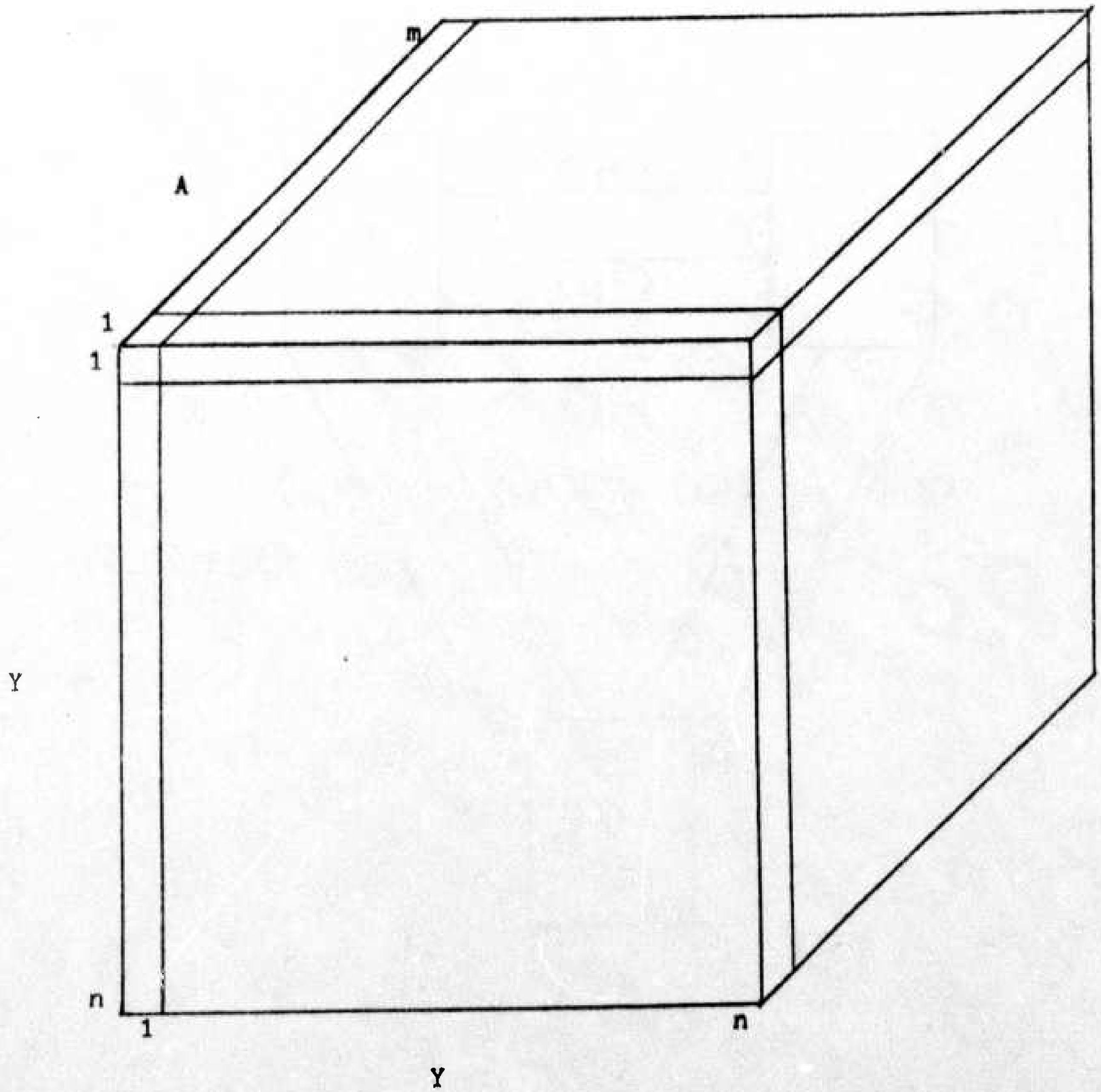


Figure 3: A Triad

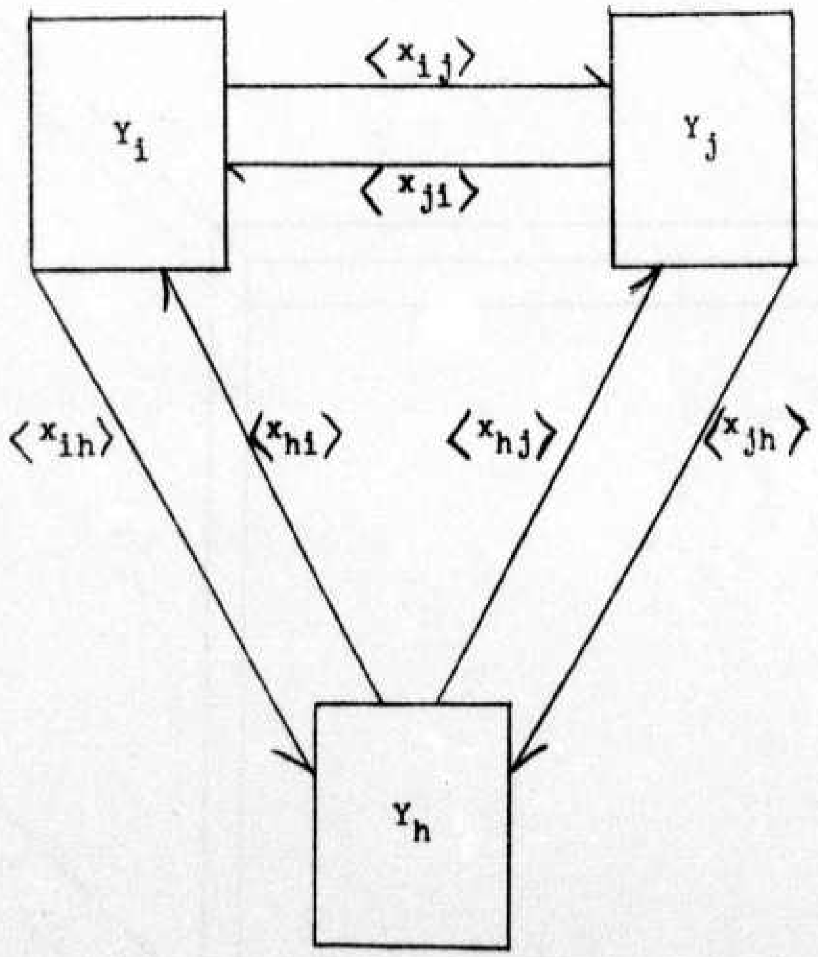
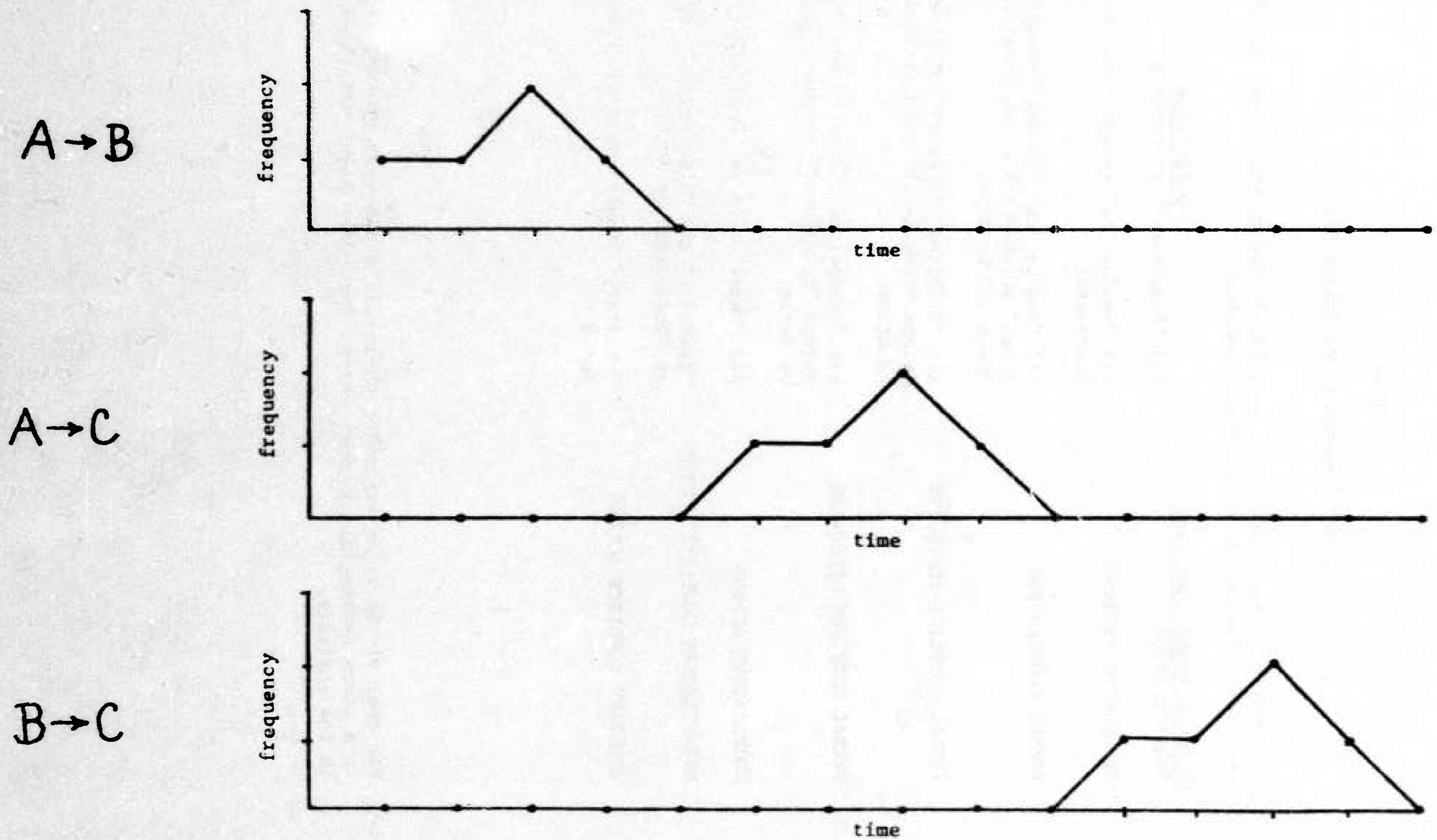


Figure 4



An example of the Sequencing of Behavior in three dyads.

Table 1

Eight Behavioral Variables Used

The eight behavior types (behavioral variables) used in this study are derived from the Sequential Action Scheme of the CREON codebook.

	Variable Number and Name	Definition
b_1	PARTICIPATION	All "Procedural" statements
b_2	DIPLOMATIC EXCHANGE	All "Evaluative" except "Procedural" statements
b_3	VERBAL COOPERATION	All "Desire" and "Intent" except "Procedural" which are seen as "Desired" or "Neutral" by Actor
b_4	VERBAL CONFLICT-DEFENSIVE	All "Elicited" "Desire" and "Intent" except "Procedural" seen as "Undesired" by Actor
b_5	VERBAL CONFLICT-OFFENSIVE	All "Unelicited" "Desire" and "Intent" except "Procedural" seen as "Undesired" by Actor
b_6	COOPERATIVE ACTION	All "Deeds" seen as "Desired" by Actor
b_7	NON-MILITARY CONFLICT ACTION	"Symbolic" and "Significant" "Deeds" seen as "Undesired" by Actor
b_8	MILITARY CONFLICT ACTION	"Military" "Deeds" seen as "Undesired" by Actor

Note: For some of the eight variables there was no behavior of that type exchanged in a given subsample. In such cases, fewer than eight variables were used in the analysis.

Table 2

Annotated Canonical Structure Matrix for USR-CPR Dyad

Communality: proportion of variation of each variable involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the variables.

Degree of overlap between the two matrices.

TRACE CORRELATION 0.66946

USR BEHAVIOR	H-SQR	canonical variates* 1	2	3
Procedural	1.000	-0.110	0.823	-0.541
Diplomatic Exchange	1.000	-0.130	0.577	0.137
Verbal Cooperation	1.000	-0.083	0.412	-0.333
Verbal Conflict-Defensive	1.000	0.912	0.246	0.257
Verbal Conflict-Offensive	1.000	0.435	-0.375	-0.493
Cooperative Acts	1.000	-0.158	0.102	0.085
PROPORTION OF VARIANCE EXPLAINED USR BEHAVIOR	100.000	18.026	23.189	12.309

Proportion: Percent of variation among all the variables involved in the variates.

Loading: degree and direction of relationship of the variables with this pattern.

Percent of variation among all variables involved in the particular variates.

		1	2	3
CANONICAL CORRELATION		0.96539	0.94098	0.74029

Canonical correlation: the statistical dependence between each matched pair of variates.

CPR BEHAVIOR	H-SQR	canonical variates* 1	2	3
Procedural	1.000	-0.091	0.551	0.575
Diplomatic Exchange	1.000	-0.113	0.693	-0.597
Verbal Cooperation	1.000	0.230	0.391	0.436
Verbal Conflict-Defensive	1.000	0.225	-0.327	-0.632
Verbal Conflict-Defensive	1.000	0.935	0.128	0.012
Non-military Conflict Acts	1.000	0.558	0.091	0.193
PROPORTION OF VARIANCE EXPLAINED CPR BEHAVIOR	100.000	21.838	17.798	21.900
PROPORTION OF TOTAL VARIANCE EXPLAINED	100.000	19.932	20.494	17.104

Percent of variation among all the variables involved in the variates.

Percent of variation among all variables involved in the particular variates.

Percent of variation among all the variables involved in the variate pairs.

Percent of variation among all the variables involved in the particular variate pairs.

* Only those variates with canonical correlations greater than .50 are presented.

Table 3

Annotated Canonical Structure Matrix for USA-CPR Dyad

Communality: proportion of variation of each variable involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the variables.

Degree of overlap between the two matrices.

TRACE CORRELATION 0.55871

CPR BEHAVIOR	H-SQR	canonical variates* 1	2	3
Participation	0.781	0.593	0.197	-0.234
Diplomatic Exchange	0.754	0.051	-0.303	-0.265
Verbal Cooperation	0.235	0.049	-0.150	-0.165
Verbal Conflict-Defensive	0.658	-0.348	0.600	-0.265
Verbal Conflict-Offensive	0.878	0.309	-0.091	0.293
Cooperative Acts	0.857	-0.229	0.112	0.321
Non-Military Conflict Acts	0.872	0.118	-0.347	-0.341
Military Conflict Acts	0.390	0.034	-0.173	-0.127

Proportion: Percent of variation among all the variables involved in the variates.

Loading: degree and direction of relationship of the variables with this pattern.

PROPORTION OF VARIANCE EXPLAINED CPR BEHAVIOR	67.795	8.004	8.552	6.798

Percent of variation among all variables involved in the particular variates.

CANONICAL CORRELATION	0.83156	0.74401	0.56199

Canonical correlation: the statistical dependence between each matched pair of variates.

USA BEHAVIOR	HSQR	canonical variates* 1	2	3
Diplomatic Exchange	1.000	0.860	0.417	0.125
Verbal Cooperation	1.000	-0.323	0.856	-0.311
Verbal Conflict-Defensive	1.000	0.158	0.192	0.597
Verbal Conflict-Offensive	1.000	0.087	-0.009	0.616
Cooperative Acts	1.000	-0.060	-0.317	-0.147
Military Conflict Acts	1.000	-0.022	-0.152	-0.208

Percent of variation among all the variables involved in the variates.

Percent of variation among all variables involved in the particular variates.

PROPORTION OF VARIANCE EXPLAINED USA BEHAVIOR	47.696	14.689	17.792	15.215

Percent of variation among all the variables involved in the variate pairs.

Percent of variation among all the variables involved in the particular variate pairs.

PROPORTION OF TOTAL VARIANCE EXPLAINED	33.786	10.869	12.512	10.405

* Only those variates with canonical correlations greater than .50 are presented.

Table 4

Annotated Canonical Structure Matrix for CPR-JPN Dyad

Communality: proportion of variation of each variable involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the variables.

Degree of overlap between the two matrices.

TRACE CORRELATION 0.54849

		canonical variates*	
CPR BEHAVIOR	H-SQR	1	2
Diplomatic Exchange	0.732	-0.010	-0.244
Verbal Cooperation	0.909	-0.210	0.634
Verbal Conflict-Offensive	1.000	0.344	0.447
Cooperative Actions	1.000	0.446	0.724
Non-Military Conflict Acts	1.000	-0.243	0.924

Loading: degree and direction of relationship of the variables with this pattern.

Proportion: Percent of variation among all the variables involved in the variables

PROPORTION OF VARIANCE EXPLAINED CPR BEHAVIOR	92.813	8.404	40.771

Percent of variation among all variables involved in the particular variates.

CANONICAL CORRELATION		0.87992	0.56411

Canonical correlation: the statistical dependence between each matched pair of variates.

		canonical variates*	
JPN BEHAVIOR	H-SQR	1	2
Diplomatic Exchange	1.000	-0.151	-0.174
Verbal Cooperation	1.000	-0.209	0.526
Verbal Conflict-Offensive	1.000	-0.259	0.734
Cooperative Acts	1.000	0.925	0.312

Percent of variation among all the variables involved in the variates.

Percent of variation among all variables involved in the particular variates.

PROPORTION OF VARIANCE EXPLAINED JPN BEHAVIOR	100.000	23.659	23.561

Percent of variation among all the variables involved in the variate pairs.

Percent of variation among all the variables involved in the particular variate pairs.

PROPORTION OF TOTAL VARIANCE EXPLAINED	96.007	15.184	33.122

* Only those variates with canonical correlations greater than .50 are presented.

Tablo 5

Annotated Canonical Structure Matrix for USA-USR Dyad

Communality: proportion of variation of each variable involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the variables.

Degree of overlap between the two matrices.

TRACE CORRELATION 0.62889

USA BEHAVIOR	H-SQR	canonical variates* 1	2	3	4
Procedural	1.000	0.758	0.467	0.312	0.129
Diplomatic Exchange	1.000	0.194	0.642	-0.170	0.346
Verbal Cooperation	1.000	-0.024	0.867	-0.346	-0.009
Verban Conflict-Defensive	1.000	-0.572	0.420	0.030	0.496
Verbal Conflict-Offensive	1.000	-0.381	0.749	0.255	-0.423
Cooperative Acts	1.000	0.179	0.630	0.033	-0.456
Non-Military Conflict Acts	1.000	-0.359	0.532	0.110	-0.526
PROPORTION OF VARIANCE EXPLAINED USA BEHAVIOR	100.001	17.802	39.986	4.650	15.043
CANONICAL CORRELATION		0.91712	0.88606	0.74978	0.68522

Proportion: Percent of variation among all the variables involved in the variates.

Loading: degree and direction of relationship of the variables with this pattern.

Percent of variation among all the variables involved in the variates.

Canonical correlation: the statistical dependence between each matched pair of variates.

USR BEHAVIOR	H-SQR	canonical variates* 1	2	3	4
Procedural	1.000	0.701	0.642	-0.085	0.055
Diplomatic Exchange	1.000	-0.129	0.630	-0.687	0.219
Verbal Cooperation	1.000	0.118	0.801	0.475	0.167
Verbal Conflict-Devensive	1.000	-0.236	0.016	0.262	0.120
Verbal Conflict-Offensive	1.000	-0.450	0.109	0.023	0.563
Cooperative Acts	1.000	-0.281	0.554	-0.265	-0.728
Non-Military Conflict Acts	1.000	0.024	-0.020	-0.307	-0.277

Percent of variation among all the variables involved in the variates.

Percent of variation among all variables involved in the particular variates.

PROPORTION OF VARIANCE EXPLAINED USR BEHAVIOR	100.000	12.285	25.281	13.397	14.531
PROPORTION OF TOTAL VARIANCE EXPLAINED	100.000	15.043	32.633	9.024	14.787

Percent of variation among all variables involved in the variate pairs.

Percent of variation among all the variables involved in the particular variate pairs.

* Only those variates with canonical correlations greater than .50 are presented.

Table 6

Annotated Canonical Structure Matrix for USA-JPN Dyad

Communality: proportion of variation of each variable involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the variables.

Degree of overlap between the two matrices.

TRACE CORRELATION → 0.59541

USA BEHAVIOR	H-SQR	canonical variates* 1	2	3
Procedural	0.927	-0.221	0.169	-0.775
Diplomatic Exchange	0.955	0.753	0.276	-0.345
Verbal Cooperation	0.913	0.698	-0.403	0.098
Verbal Conflict-Offensive	0.194	-0.191	0.007	-0.309
Cooperative Acts	0.819	-0.039	0.789	0.382

Proportion: Percent of variation among all the variables involved in the variates.

Loading: degree and direction of relationship of the variables with this pattern.

PROPORTION OF VARIANCE EXPLAINED USA BEHAVIOR	76.167	22.837	17.768	19.406

Percent of variation among all the variables involved in the variates.

CANONICAL CORRELATION	0.83698	0.62888	0.54161

Canonical correlation: the statistical dependence between each matched pair of variates.

JPN BEHAVIOR	H-SQR	canonical variates* 1	2	3
Diplomatic Exchange	1.000	0.606	-0.597	0.137
Verbal Cooperation	1.000	0.034	0.573	-0.664
Verbal Conflict	1.000	0.977	0.126	0.092
Cooperative Acts	1.000	-0.173	0.508	0.630

Percent of variation among all the variables involved in the variates.

Percent of variation among all variables involved in the particular variates.

PROPORTION OF VARIANCE EXPLAINED JPN BEHAVIOR	100.001	33.832	23.960	21.611

Percent of variation among all the variables involved in the variate pairs.

Percent of variation among all the variables involvad in the particular variate pairs.

PROPORTION OF TOTAL VARIANCE EXPLAINED	86.760	27.724	20.520	20.386

* Only those variates with canonical correlations greater than .50 are presented.

Table 7

Annotated Canonical Structure Matrix for USR-JPN Dyad

Communality: proportion of variation of each variable involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the variables.

Degree of overlap between the two matrices.

TRACE CORRELATION 0.42694

	canonical variates*	
USA BEHAVIOR	H-SQR	1
Diplomatic Exchange	1.000	-0.269
Verbal Conflict-Devensive	1.000	-0.426
Cooperative Acts	1.000	-0.431
Non-Military Conflict Acts	1.000	-0.510
Military Conflict Acts	1.000	0.826

Proportion: Percent of variation among all the variables involved in the variates.

Loading: degree and direction of relationship of the variables with this pattern.

PROPORTION OF VARIANCE EXPLAINED USR BEHAVIOR	100.000	27.631

Percent of variation among all the variables involved in the variates.

CANONICAL CORRELATION	0.67998

Canonical correlation: the statistical dependance between each matched pair of variates.

	canonical variates*	
JPN BEHAVIOR	H-SQR	1
Diplomatic Exchange	1.000	-0.401
Verbal Cooperation	1.000	-0.215
Verbal Conflict-Defensive	1.000	0.010
Verbal Conflict-Offensive	1.000	0.622
Cooperative Acts	1.000	0.444

Percent of variation among all the variables involved in the variates.

Percent of variation among all variables involved in the particular variates.

PROPORTION OF VARIANCE EXPLAINED JPN BEHAVIOR	100.000	15.824

Percent of variation among all the variables involved in the variate pairs.

Percent of variation among all the variables involved in the particular variate pairs.

PROPORTION OF TOTAL VARIANCE EXPLAINED	21.728	21.728

* Only those variates with canonical correlations greater than .50 are presented.

Table 8

Trace Correlation for the Impact of Salient and Non-Salient Actors Foreign Policy Actions in each Dyad.

	Salient	Non-Salient	Predicted
USA-JPN	.39	.30	Yes
USA-USR	.53	.45	Yes
USR-JPN	.47	.56	No
USR-USA	.49	.47	Yes
JPN-USA	.41	.38	Yes
JPN-USR	.49	.40	Yes
CPR-USA	.47	.47	No
CPR-USR	.39	.52	No
CPR-JPN	.39	.47	No
USA-CPR	.42	.48	No
USR-CPR	.39	.50	No
JPN-CPR	.39	.23	Yes

FOOTNOTES

1. In this paper we will use the following notation:

   $= \{ \quad \}$ indicates a set

   : means "such that"

   $\in$ means "is a member of the set . . .

   < > indicates a vector

   $\cup$ means the union of two sets

   $\cap$ means the intersection of two sets

   ′ means the transpose of the vector or matrix

   < >$_{n \times m}$ means that the vector or matrix has dimensions n rows by m columns

   · means the inner product of two vectors or matrices

2, For an extended discussion of alternative approaches to the concept of time in social theories, see Rummel (1970) or Smoker (1971).

3. See Rummel & Hall (1969), Lorimor & Phillips (1972), and McClelland (1972).

BIBLIOGRAPHY

Azar, Edward A. (1970). "Profiling and Predicting Patterns of Inter-Nation Interactions: A Signal Accounting Model." Paper presented to the American Political Science Association Annual Meeting. Los Angeles, California (September).

Bartos, Otamar (1966). "Concession Making in Experimental Negotiations." In Joseph Berger, Morris Zelditch, Jr., and Bo Anderson (eds.) Sociological Theories in Progress. New York: Houghton Mifflin.

Bronfenbrenner, Urie (1961). 'The Mirror Image in Soviet-American Relations" Journal of Social Issues, 17, pp. 45-46.

Brunner, Ronald P. (1970), "Data Analysis, Proven Analysis and System Change." Paper prepared for the 66th Annual Meeting of APSA.

Burton, John (1968). Conflict and Communication. New York: Free Press.

Davis, Philip J. (1965). The Mathematics of Matrices. Toronto: Ginn-Blaisdell.

Harary, Frank (1961). "A Structural Analysis of the Situation in the Middle East in 1956." Journal of Conflict Resolution, pp. 167-178.

Hibbs, Douglas A (1972). "Problems of Statistical Estimation and Causal Inference in Dynamic, Time-Series Regression MOdels". Paper prepared for delivery at the 1972 APSA meetings.

Holsti, Ole R, Robert C. North and Richard Brody (1968). 'Perception and Action in the 1914 Crisis" in J.David Singer (ed.) Quantitative International Politics: Insights and Evidence. New York: Free Press.

McClelland, Charles A. (1961). "The Acute International Crisis." World Politics. 14 (October), pp. 182-204.

__________, (1966). Theory and the International System. London: The Macmillan Co.

__________, (1968) "Access to Berlin: The Quantity and Variety of Events, 1948=1963." In J. David Singer (ed.) Quantitative International Politics: Insights and Evidence. New York: Free Press, pp. 159-186.

_____________, Daniel P. Harrison, Wayne R. Martin, Warren R. Phillips and Robert A. Young (1965). The Communist Chinese Performance in Crisis and Non-crisis: Quantitative Studies of the Taiwan Straits Confrontation, 1950-1964. China Lake, California, U.S. Naval Ordinance Test Station, NOTS TP 4138, (May).

North, et. al.(1968). See Holsti, North and Brody.

Orcutt, Guy H., Harold W. Watts, and John B. Edwards (1968). "Data Aggregation and Information Loss." American Economic Review. Vol. 68 (September) pp. 773-787.

Phillips, Warren R. (1971). "The Dynamics of Behavioral Action and Reaction in International Conflict." Papers of the Peace Research Society.

_____________, (1972). "The Conflict Environment of Nations: A Study of Conflict Inputs to Nations in 1963." In J. Wilkenfeld (ed.) Conflict Behavior and Linkage Politics. New York: McKay.

_____________ (1972). "Major Power Conflict Exchanges in the Sixties: A Triadic Analysis of the Soviet, U.S. and Chinese Sub-System from a Comparative Foreign Policy View." Columbus: The Ohio State University (mimeo).

_____________ (1973). "Two Views of Foreign Policy Interaction: Substantially the Same or Different?" To appear in Azar and Ben Dah, International Interactions. New York: Gordon and Breach.

_____________ and Robert C. Crain (1972). "Dynamic Foreign Policy Interactions: Reciprocity and Uncertainty in Foreign Policy." To be published in the International Yearbook of Foreign Policy Studies.(1974) Los Angeles: Sage Publications.

Rummel, Rudolph J. (1963). "Dimensions of Conflict Behavior Within and Between Nations." General Systems: Yearbook of the Society for General Systems Research, VIII, pp. 1 50.

Smoker, Paul (1969). "A Time Series Analysis of Sino-Indian Relations." Journal of Conflict Resolution. XIII (June) pp. 172-191.

Stagner, Ross (1967). Psychological Aspects of International Conflict. Belmont California: Brooks and Cole.

Tanter, Raymond (1966). "Dimensions of Conflict Behavior Within Nations 1958-1960." Journal of Conflict Resolution, X (March), pp. 41-64.

______________ (1972). "International System and Foreign Policy Approaches: Implications for Conflict Modeling and Management." World Politics, XXIV, pp. 7-39.

Thorson, Stuart J. (1971). "Modeling Social Processes as Dynamic Systems." Paper presented to APSA meeting in Chicago.

Wilkenfeld (1968). "Domestic and Foreign Conflict Behavior of Nations." Journal of Peace Research. Vol. V, No. 1, pp. 56-69.

Zinnes, Dina (1968). "The Expression and Perception of Hostility in Prewar Crisis: 1914." In J. David Singer (ed.) Quantitative International Politics: Insights and Evidence, New YOrk: Free Press.

Major Power Conflict Exchanges in the Sixties: A Triadic Analysis of the U.S., Soviet, and Chinese Sub-System From a Comparative Foreign Policy View

Warren R. Phillips
Associate Professor
Project for Theoretical Politics
Ohio State University

and

Michael K. Hainline
Department of Political Science
Ohio State University

Project Research Paper No. 5

Prepared in connection with research supported by the Advanced Research Projects Agency, ARPA Order No. 2345-3D20, Contract No. DAHC 15 73 C 0197, RF 3527-A1.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

Project for Theoretical Politics
The Ohio State University
053 Administration Building

2a. REPORT SECURITY CLASSIFICATION

UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

"Major Power Conflict Exchanges in the Sixties: A Triadic Analysis of the U.S., Soviet, and Chinese Sub-System From a Comparative Foreign Policy View"

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Research Report # 5

5. AUTHOR(S) (First name, middle initial, last name)

Warren R. Phillips
Michael K. Hainline

6. REPORT DATE

June 30, 1973

7a. TOTAL NO OF PAGES

55

7b. NO. OF REFS

35

8a. CONTRACT OR GRANT NO

DAHC15 73 C 0197

b. PROJECT NO

A.O. 2345-3D20

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

5

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited and production in whole or in part is permitted for any purpose of the United States Government.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

Advanced Research Projects Agency
Washington, D.C.

13. ABSTRACT

Increasingly observers have come to recognize the importance of examining the effects of third parties on the behavioral exchanges between two nations. No where is this more clearly evidenced than in the case of the relations between the United States, the Soviet Union, and China. The attempt is thus made in this paper to ascertain the impact of each of the dyadic exchanges among these three nations on the other behavioral exchanges in the triadic subsystem they form. The findings of the study clearly show that when considering the exchanges between any two of these nations, policy makers must also consider what is happening in the other parts of the triad. These third party exchanges are found to add considerably to the explanation of specific strategies employed by the three nations.

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Third parties						
United States, USSR, China						
Reciprocity						
Bureaucratic inertia						
"United Front"						
Disengagement						
Coordination of hostilities						
Strategies						

Major Power Conflict Exchanges In The Sixties:
A Triadic Analysis Of The U.S., Soviet, And Chinese Sub-System
From A Comparative Foreign Policy View

Introduction

The period since World Wsr II has been well established as a cold war era in which the Soviet Union and the United States were the major competitors for world dominance. More recently established, but growing in acceptance, has been the recognition of a triadic relationship with the Chinese ascending to a major role in the international arena. With this ascendency, it has become increasingly important to seek insights into the foreign policy linkages between these three major antagonists of the cold war. To this end, the conflict exchanges between all three nations are analyzed in this study. In particular, this paper views foreign policy exchanges in a dyadic fashion, but seeks to ascertain the impact upon each of the dyadic exchanges of other behavioral exchanges in the triangle. To accomplish this task, a distinction will be made between the direct effect of the target nation and the indirect effect of other dyads in the triangle upon the choice of an actor's behavior.

The Seeds of Conflict

All great conflicts gather a momentum of their own which persists and grows even after the causes that initially provoked the conflict have abated, if not ceased; the cold war is no exception. Several events which occurred following the Second World War can be suggested as having influenced the trend in conflict exchanges between China, the Soviet Union, and the United States. Included among these would be the Berlin blockade, the Korean invasion, the first Soviet detonation of a nuclear device, the accession to power by the Chinese Communists, and the Vietnam conflicts.

A great fear for U. S. strategists, evident since World War II, has been

that a hostile power or combination of powers might succeed in uniting Eurasia and turning its vast resources against the West. In this light, the association of the word "conflict" with the Soviet Union represents an almost visceral response for many Americans, accustomed as they are to the rhetoric of the cold war. The United States seems to have initially placed the Soviet Union in the role of the main perpetrator of world-wide revolutionary activity and of the leading member of an Eurasian alliance with China. More recent events have led to a major re-evaluation of this view, however (Kaplan, 1970; Morris, 1968; Zimmerman, 1971).

The Soviet Union has also faced the post-World War II period with a series of reassessments of its policies, stemming from several major events: the launching of the first Sputnik and the related development of ICBM's, the rapid development of American ICBM's, the Cuban Missile Crisis, and the Sino-Soviet-split. Various combinations of these events have been used to explain Soviet relations with the United States (Aspaturian, 1968; Dinerstein, 1968, Lowenthal, 1968b; Zimmerman, 1968, 1969, 1971).

The relations between the United States and the Chinese People's Republic have been relatively consistent throughout this period. Until very recently, Sino-American relations have been characterized by an atmosphere of intense hostility and rivalry between these two nations. The foundation of these relations was set in the early years of the Chinese Communist state with three major confrontations experienced by China and the United States; the first was in Korea. It was followed by the crises in the Taiwan Straits and finally by the conflict in the former French colonies of Indo-China (Friedman, 1971, Halperin, 1965; Lowenthal, 1968a).

Several major events have marked Sino-Soviet relations in much the same way as the relations between the United States and China were affected. Relations between these two great Communist nations seem to have initially been cast in terms of an alliance against the encircling capitalist nations, with the Soviets as the guiding member. But several events have led to a dissolution of this alliance and the development of a mutual view of one another as a serious obstacle to the interests of the other. Chinese initiatives towards the "Third World": beginning with the first Bandung conference, the Soviet refusal to help the Chinese in the Quemoy-Matsu crises of 1958, and the Soviet support of India in the 1962 Sino-Indian border crisis all underscore an increasingly conflictual relationship between the Soviet Union and the Chinese People's Republic (Dinerstein, 1971; Lowenthal, 1968a; Tsou, 1965; Zagoria, 1968).

The post-World War II period of relationships between these three nations clearly suggests that these three world powers have been engaged in a series of conflict of interest and tests of will or determination. More subtly, the events of the past two decades seem to suggest that the actions between the two nations in a given dyad are not lost on each other. That is, the actions of any two opponents, toward each other or toward the third actor, appear to have important implications for the relations of the third actor to either opponent. Thus, Soviet-American relations may very well affect China's relations with both the Soviet Union and the United States. The efforts by the Soviet Union and the United States to reach an accommodation, for example, have been suggested as a principle reason for the increased hostility in Sino-Soviet relations (Aspaturian, 1968; Lowenthal, 1968a; Tsou, 1965). In addition, China's rise in political importance prevents the United States from treating the Soviet Union as the sole enemy precisely

because the United States cannot act as though the danger comes only from actual military capabilities (Hoffman, 1968). For similar reasons, the Soviet Union must be restrained in its efforts to reach a rapprochement with the United States for fear of losing out to the Chinese in the struggle for influence in the Third World. The linkage between these three nations is demonstrated in the following remarks by Herbert Dinerstein:

> A useful definition of cold war is a state in which opponents who differ ideologically expect tension to mount steadily and possibly culminate in war. When tension waxes and wanes and rapprochement and detente are conceivable, "cold war" no longer describes the situation. This definition of cold war applies equally well to Sino-American and to Sino-Soviet relations. Sino-American relations are very limited at present and may continue so, but the general expectation is that they will improve somewhat, not that they will inexorably worsen. The Soviet Union fears modest improvements because only old-fashioned cold war between the United States and China can force the Chinese back into the same relationship with the Soviet Union that obtained during and immediately after the Korean war. Active U.S.-Chinese hostility obviously pushes the Chinese toward rapprochement. Distant, if not friendly, relations with the United States either make it unnecessary for the Chinese to accept Soviet terms or permit them to bargain on a better basis. As the familiar binding elements of alliances, the common enemy, becomes effaced, a possible Sino-Soviet rapprochement has to be on a different basis. If one assumes that the Vietnamese War will end and that some moderate regularization of Sino-American relations will occur, then it is difficult to posit the restoration of the status quo ante in Sino-Soviet relations. (Dinerstein, 1971, p.95).

In this paper, the exchanges between these three nations are analyzed in an attempt to discover just how closely interlocked are the behaviors between them.

<u>Foreign Policy Linkages in Complex Systems</u>

The rationale for this analysis of the interlocking of the relations between China, the Soviet Union , and the United States can be developed in more abstract and formal terms. It is an accepted truism today that the world is getting smaller, that events in remote parts of the world have an intimate

bearing upon one another. Political units which at one time were autonomous are no longer so today. The geographical and legal boundaries between nations do not pose the great barriers they once did. International relations theorists have not been slow to recognize the impact of international interactions on national autonomy. Boulding (1962) notes that the legal boundary of a nation may no longer be the most salient for research purposes. Demonstrating various relations between pairs of nations, Boulding cites the example in which power has increased to the extent that each nation is capable of destroying the other nation at long distances, but without being able to prevent its own destruction. When this point is reached, each nation continues to exist only with the permission of the other. Boulding has coined a term for this condition: "conditional viability". Closely related to this concept is the concept of "permeability" suggested by John Herz (1957, 1959). Specifically, Herz suggests that the territorial boundaries of a nation are more permeable today then they have ever been. That is to say, external influences are able to move through national boundaries and to affect the decision-making within that state more easily than ever before. However, "...systematic conceptual exploration of the flow of influence across the changing boundaries of national and international systems has yet to be undertaken and is long overdue." (Rosenau, 1969, p.3). The present study represents, in part, the development of a technique for taking account of these influcences. To accomplish this goal we introduce the concept of "autonomy."

The question that arises here is: are the actions of the three major conflictual participants in the international system to be treated as autonomous or as linked to each other's activity? If two nations are autonomous,

then in Deutsch's graphic terms, ". . . when Mr. Leonid Brezhnev (and before him Mr. Khrushchev) is itching, the Chinese are not scratching, or are scratching their own place." (1966, P. 5). If the two systems are not autonomous, then it is impossible to understand the actions of one without reference to the actions of the other, and in Deutsch's terminology, when Brezhnev itches the Chinese are scratching. If the behavioral exchanges between all three nations interact strongly, it is then possible to treat the three nations as a subsystem.

A fundamental property of system units is that they can be coupled or linked. That is, two or more system units (or nations) can be regarded as coupled to form a single sub-system. There are two ways of achieving this linkage. One way is by forcing the coupling as two automobiles may be locked together after a head-on collision. By way of analogy, the process may well be just what is happening when we group a set of nations together without concern for the effect the linkage has upon the conditions of the new sub-system. To understand this systems problem, let us begin by organizing the facts of international relations according to two points of reference, the actor and interactions. McClelland (1966) suggests that the block diagram in Figure 1 symbolizes international relationships of whatever variety, once the relationships are broken down into their most elementary form:

> The conception of the international system is an expanded version of the notion of two actors in interaction. A view of a whole phenomenon is involved. The outermost boundaries of international relations are suggested if we imagine all of the exchanges, transactions, contacts, flows of information and actions of every kind going on at this moment of time between and among the separately constituted societies of the world. (McClelland, 1966, p.20).

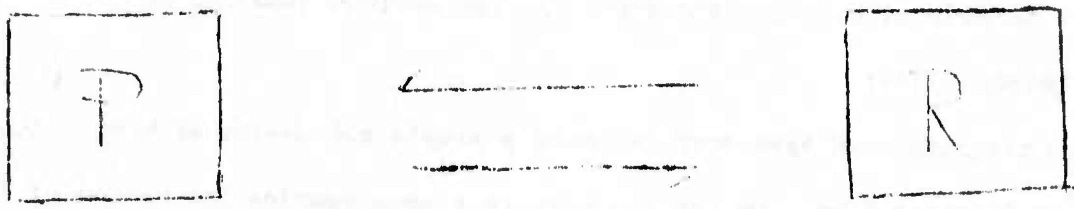


Figure 1. Basic Pattern of Interaction

International relations are then conceived to be the consequences of the vast numbers of particular purposes, intentions, expectations, and efforts on the part of national decision makers which do not necessarily mutually influence one another. Yet, some strands of action and reaction do affect each other directly. Some events heighten the linkage between nations. The point to be made here is that the linkage must be made with regard to linking inputs and outputs, with other parts being left alone no matter how readily accessible they may be.

It is our position in this paper that the analysis of the system can be made rigorous. We shall begin with two nations, P and R. There are two types, or ways, of coupling these nations. The first way is when P is coupled to R such that P's changes in behavior affect or determine in some way what R's behavior or change in behavior will be, but P's changes do not depend upon what behavior R is exhibiting. Thus, P can be said to be <u>dominant</u> over R. The second coupling occurs when the two nations are linked in such a way that they both affect each other's behavior; such a relationship can be said to be <u>co-determined</u>. It is necessary to point out that the defining of the component parts of the system does not determine the way of coupling. The corollary to this statement is that a whole system, built upon its parts' given behavior, is not sufficient to determine its behavior as a whole. Only

when the details of coupling are added can the whole's behavior be determined. (Ashby, 1952).

To this point, we have been defining a simple sub-system with only two nations and interaction. We can now move to a more complex sub-system of more than two entities. When this is done, we must define direct and indirect effects. When two nations, P and R, are coupled in such a way that a change in the behavior of one nation affects a change in the behavior of the other during a given time period, say a month, the effects are termed <u>direct effects</u>. The actions of nation P to nation R may thus have a direct effect upon the actions of nation R to nation P. In addition, the actions of nation R to nation P may indirectly affect P's actions to a third nation, Q. The effects of the relations between two nations upon another relationship in a complex sub-system are termed <u>indirect effects</u>.

Now that we have specified the types of linkage which are possible, and distinguished betwe n different forms of effects, we must delineate the form of relationships conceptually developed above. This is partially accomplished with the following equation:

$$B_{R \to P,k,t} = \sum_{\ell=1}^{m} \alpha_\ell B_{P \to R,\ell,t} \qquad (1)$$

where $B_{R\,P,k,t}$ is the behavior of nation R directed toward nation P on dimension k at time t.

$\sum_{\ell=1}^{m} \alpha_\ell B_{P\,R,\ell,t}$ is the weighted sum of each of nation P's behaviors toward R, as measured respectively along the m dimensions of behavior. The weights (α's), used in computing the sum, are the relative importance of nation P's behavior on each dimension in influencing the behavior of nation R on the dimension k.

This equation states as a working hypothesis that a nation's behavior results from the patterns of action of its object or opponent, i.e., reciprocity. Other works in international relations (e.g., Tanter, 1972; Bartos, 1966)

have suggested similar hypotheses.

But certainly international relations is more than a tennis match in which each actor's response is to his opponent's service. There are over-time forces at work within a nation which influence the choice of a specific strategy. These forces lead to an **inertia** in the way one nation treats or acts toward a specific object nation. The actions conform to Halperin's statement that "...most of the actions taken by bureaucracies involve doing again or continuing to do what was done in the past. In the absence of some reason to change their behavior, orgainzations keep doing what they have been doing." (1970, p.9). This bureaucratic **inertia** in explaining the performance of foreign policy organizations is appealing and leads to the working hypothesis that a nation's behavior in foreign policy results from its own prior patterns of actions. Stated formally:

> A given nation's level of output toward a specific object nation is a product of the previous level of output.

Mathematically, this can be translated into the linear euqation

$$B_{R \to P,k,t} = \alpha_k B_{R \to P,k,t-1} \tag{2}$$

where the symbolization is identical to equation (1) and t-1 is the time period one duration earlier.

Equation (1) and (2) can be joined to form a single qquation:

$$B_{R \to P,k,t} = \alpha_k B_{R \to P,k,t-1} + \sum_{\ell=1}^{m} \alpha_\ell B_{P \to R,\ell,t} \tag{3.1}$$

where the symbolization remains the same as in the two preceding equations. What this equation states mathematically is the contention that a given nation's level of foreign policy output toward that opponent u function of the opponent nation's level of output along each of the foreign policy

dimensions. Put more simply, behavior is a function of bureacratic inertia and reciprocity.[1]

Equation (3.1) fully operationalizes the concept of direct linkage. When systematic planning involves either a direct response to an object nation's actions or is based upon consistent actions followed over time, a direct link between nation R and P is established. In the earlier discussion of dominant relationships versus co-determined relationships it was noted that if R's behavior to P is affected by P, and P's behavior to R is not affected by R, then the relationship is a dominant relationship of P over R. Analyzing the foreign policy exchanges between P and R, if there is a difference in the percentage of variance explained from P to R as opposed to that explained in the behavior from R to P, we can identify a dominant relationship in which the case for dominance is determined by the larger percentage of variance explained. If the percentage of variance explained is low for both P to R and R to P, the nations are autonomous and act without regard to each other's behavior.

When it is applied to an empirical case such as the relationship between the Soviet Union and the United States, equation, (3.1) will spell out the relative influence of inertia and reciprocity on the responses of the actor nation. The parameter weights (α s) would identify the "normal" response behavior in the relationship between the two nations. When these parameter weights are determined, we can estimate what each nation's response behavior will be from knowledge of the particular mixture of its prior behavior and the

---

[1]For a further development on the relationship between foreign policy exchanges and the forces of interia and reciprocity, see Philips (1972a) and Phillips and Crain (1972).

behavior it receives from the object nation. Equation (3.1) can thus be written such that

$$\hat{B}_{R\ P,k,t} = \alpha B_{R\ P,k,t-1} + \sum_{\ell=1}^{m} \alpha_{\ell}\ B_{P\ R,\ell,t} \tag{3.2}$$

where $\hat{B}_{R\ P,k,t}$ denotes the estimated response of the actor nation.

While the forces affecting the response behaviors of the United States and the Soviet Union may be fixed from one time period to the next, the actual response behavior of each actor may not. That is to say, for a given expectation of response behavior, there would be a residual amount of each nation's response behavior which is not explained by inertia and reciprocity. The difference between the observed and the expected response behavior (the residual response of each nation) represents the over- or under-response in the relationship between the two nations. Where the Soviet Union's expected behavior to the United States, for example, exceeds its actual behavior, the Soviet Union is under responding to the United States. Conversely, where the actual behavior of the Soviet Union to the United States exceeds its expected behavior, the Soviet Union is said to be over-responding to the United States.

This over- and under-response is conceptualized here to be potentially explainable by the indirect effects of behavioral relations in the other dyads of the triangular sub-system of the Soviet Union, the United States and China. For the specific case of the Soviet Union's behavior to the United States, the direct effects are examined by analyzing the United States' behavior to the Soviet Union and past Soviet action toward the United States. The over- or under-response of the Soviet Union is then analyzed by examining the indirect effects of the Soviet Union's behavior to China, China's actions

toward the Soviet Union, Chinese behavior to the United States, and the United States' behavior to China. Thus, there are four possible indirect effects and two direct effects for each relationship. Equation (4) formalizes the impact of indirect effects:

$$B_{R \to P,k,t} - \hat{B}_{R \to P,k,t} = \sum_{q=1}^{m} \gamma_q I_{q,t} \tag{4}$$

where $B_{R \to P,k,t} - \hat{B}_{R \to P,k,t}$ is the residual behavior from nation R to nation P left unexplained after inertia and reciprocity have been considered. That is, it is the over- or under-response of nation R to nation P.

$\sum_{q=1}^{m} \gamma_q I_{q,t}$ is the weighted sum of the behavioral relations in the other four dyads of this triangular sub-system. The weights (γ's) are the relative importance of the relations between the nations in these other dyads on m dimensions.

Analysis of the Data

In order to analyze the relations between the Soviet Union, the United States, and China, data were drawn from the foreign conflict code sheets of the Dimensionality of Nations Project (Rummel, 1966). Included in the data were the conflict events exchanged between these three nations during the time period June 1962 to May 1968, 72 months of data. The data were orgainzed into a super P matrix of 21 variables (Table 1) over the 72 months for each of the six dyads, or 432 observations (Figure 2). This matrix was then factor analyzed to delineate the basic patterns of conflict exchanges for this triangular sub-system.[2] Table 2 presents the orthogonally rotated factors from this analysis. Eight factors, or patterns, emerged with eigenvalues of 1.0 or greater. Together, these eight factors accounted

---

[2] The twenty-one variables were standarized by column and correlated (i.e., transformed) by product-moment correlations. Component factor analysis was employed to delineate principal axes which were rotated to a simple structure solution by varimax criteria.

for 77.3 percent of the total variance in the original conflict matrix. Not all of the variables were well accounted for by these eight factors, however. Two variables, "protests" and "non-violent behavior acts", were particularly not well accounted for as evidenced by their low communalities: .44 and .27 respectively. In the case of the other 19 variables, 53.3 to 99.9 percent of their variance was accounted for by the eight factors.

A close examination of the factor loading matrix reveals that these factors represent eight distinct patterns, or dimensions, of conflict behavior. That is, the variables loading highest on each factor come from a particular area in the original list of variables. The first factor is thus characterized by a combination of acts which fall in the primary category "negative communications." The second factor highlights those acts which are classified as "official military violence." The next strongest factor, in terms of the amount of variance explained, is the fourth factor which is characterized by warning and defensive acts"; it includes alerts, mobilizations, and troop movements.

With the remaining five factors, we find a partitioning of the original variable areas "negative sanctions" and "unofficial violence" into several more specific patterns of conflict behaviors. The fifth factor is a pattern of negative sanctions, specifically unclassified negatvive behavior acts. The sixth factor is characterized by a combination of boycotts and embargoes, and aid to rebellious groups and to the object's violent enemy. Diplomatic conflict is identified with the seventh factor. In particular, this pattern of conflict exchanges includes severences or suspensions of diplomatic relations, and expulsions or recalls of diplomatic personnel. What is important to

keep in mind about this factor is that it is a bipolar factor, i.e., one high negative loading and one high positive loading. As such, the factor indicates that this pattern of conflict exchanges involves either suspensions or severences of diplomatic relations, or expulsions or recalls of diplomatic personnel, but not both types of behavior. Thus the three nations seem to choose one or the other but not both forms of behavior at a given time.

The last two factors, factors three and eight, reflect the splitting of the unofficial planned violence behaviors into two specific patterns. With the third factor, the emphasis is on those acts of unofficial violence which were aimed at personnel and private property. The eighth factor is characterized by the specific experience of attacks on governmental property, particularly embassies.

This delineation of the conflict exchanges between the Soviet Union, the United States, and China into eight patterns characterized by the prevalance of one particular type of behavior closely approximates the findings of other studies of the conflict exchanges between nations. Previous analyses (Phillips, 1969; Hall and Rummel, 1968; Oliva and Rummel, 1969; McClelland and Hoggard, 1968) have tended to point out that there are four or five major patterns of conflict exchanges which are easily identified as negative communications, negative sanctions, official military violence, warning and defensive acts or troop mobilizations, and unofficial violence. The point of departure between this study and the previous analyses comes with the partitioning of two of these major patterns into several more specific patterns of conflict exchanges as indicated above. One obvious explanation for this fractionalizing of behavior patterns rests with the

fact that we are dealing with a much smaller and more narrowly focused set of conflict dyads. As a result, we would expect those patterns that were combined in the analyses of the conflict exchanges between all nations to be separated out there due to the focusing in upon a specific sub-system.

The findings seem to indicate the use of more complex systems of conflict management by the members of this triad. The availability of a number of alternative signals (corresponding to the various patterns of conflict behavior) and the greater specificity of these signals would seem to suggest a system of conflict management designed to deal with a wide range of possible conflict situations. This complexity in the handling of the conflict with each other seems natural given two important considerations. First, these three nations have experienced high amounts of conflict between them for a long period of time. With each conflict, the nation's system for dealing with conflict situations is modified so as to be able to cope with a similar situation in the future. Secondly, each nation has developed a specialized set of experts in dealing with one or both opponents. This group of experts is likely to have a capacity for sorting out and discriminating between several different signals or behaviors which for the average dyadic exchange would be simply indistinguishable.

This brings us to the examination of the particular linkages between the Soviet Union, the United States, and China. Earlier it was suggested that the relations between any two nations were a function of two forces, inertia and reciprocity. In particular, it was proposed that a nation's foreign policy outputs to a specific opponent were a product of the actor nation's prior behavior to the opponent nation and the direct effects of the

opponent's behavior to the actor nation on each foreign policy pattern. Together, these two forces establish the direct linkages between the nations in this triangle, as formalized in equation (3.1).

In order to investigate the relative impact of inertia and reciprocity on the relations between these three nations, it was first necessary to organize the factor scores in the preceding analysis into two matrices for each relationship. The first martix represents the amount of conflict behavior sent from an actor nation (R) to an object nation (P), where the rows are considered as recording the amount of behavior on each of the eight factors in each of 71 months.[3] The second matrix was organized such that it included the behavior sent in the same time period from P to T, and the behavior sent from R to P in the time period t-1. In the case of the Unites States' behavior to China, for example, the data in the second matrix thus includes China's behavior to the United States for the time period July 1962 to May 1968 and the United States' behavior to China for the time period June 1962 to April 1968, a one month time lag.

Since both matrices contain multiple variables (eight in the first and sixteen in the second), canonical regression was employed in this analysis. Consider the following: we have two matrices, M for the amount of behavior sent, as a response, from the actor nation to the object nation, and N for the combination of the amount of conflict behavior the object sends to the actor nation and the amount of conflict behavior sent from the actor

[3]As indicated earlier, inertia refers to the impact of the level of an actor's output toward an object one duration earlier. To examine the effects of inertia, it was necessary to treat the second month in the data set (July 1962) as the beginning point in the analysis of each actor nation's behavior. The first month in the data set (June 1962) was then treated as the actor nation's behavior to an object nation at t-1. Thus, 71 rather than 72 time points were examined.

nation in the previous month. A linear transformation of M can be performed which will yield orthogonal (independent) dimensions of M. By employing canonical analysis to solve for the least squares fit between M and N, these dimensions of M will be ordered so that the first will have the maximum correlation with N, the second will have the maximum residual correlation with N, and so on. Let T be the appropriate transformation for M, and P the (necessary resulting) transformation of N. Then,

$$MT = NP + C, \text{ and}$$
$$Y = V + C$$

where $MT = Y$, $NP = V$, and C is the least-squares error. The restrictions on Y and V are:

$$Y_k' V_g = K_{kg} \text{ (canonical correlation), } k = g;$$
$$Y_k' V_g = 0, \; k \neq g;$$
$$Y_k' Y_k = V_g' V_g = 1; \text{ and,}$$
$$Y_k' Y_g = V_k' V_g = 0, \; k \neq g.$$

Thus, the research question becomes; can the two matrices be dimensionalized so that they share a good deal of the variance? Put another way, can we find patterns in both matrices which are highly correlated? The canonical model is the best representation of this research question.[4]

---

[4] While it would have been possible to use regression analysis and regress behavior sent for each of the eight behavioral variables independently upon the sixteen variables identified in the N matrix, we do not feel that this would have been appropriate. We contend that nations do not send just a single one of the eight types of behavior identified here. In essence, there are interactive effects which affect behavior sent as well as behavior received. These effects are important, and they must not be considered, _a priori_, to be nonexistent. Regression models both consider interactive effects to be nonexistent and are affected by them in uninterpretable ways when those effects are present. The canonical model is not affected by these interactive effects. For further development of this point, see Phillips (1972).

Employed with the above two matrices, the canonical method delineates linear combinations of variables from both matrices such that the combinations (or patterns) are maximally intercorrelated. At the same time, each pair of linear combinations (termed variates) will be independent of the other variates delineated in either matrix.[5]

Six canonical regressions were then performed, one for each of the six dyads in the sub-system under investigation. The canonical results are presented in Tables 3 through 8. An examination of the trace correlations ($\bar{r}$) for each dyad reveals that there is considerable overlap between the two matrices: the trace correlations range from approximately .49 to .69. In other words, twenty-five to forty-six percent of the variance in the conflict behaviors of each nation toward an object nation in this sub-system can be accounted for by the forces of inertia and reciprocity.

The nature of the direct linkages between China, the Soviet Union, and the United States can thus be visualized, as in Figure 4 where the trace correlations represent the strengths of these linkages.[6] As noted earlier, we can identify the type of coupling, or relationship, between two nations from the amount of differences in the percentage of variance explained from nation R to P as opposed to from P to R. Where there is a differential in the percentage of variance explained, the stronger relationship is said to be dominant. Conversely, where the percentage of variance is equal, the relationship is said to be co-determined. Examining Figure 4 closely, we find the

---

[5]For a further development of canonical analysis, see Morrison (1967) or Phillips (1972).

[6]The trace correlation delineates the general overlap between the two matrices of foreign policy inputs and foreign policy outputs. It represents the average expected relationship between the two pairs of variates from the spaces represented by the two matrices, M and N.

relationships in this triangular sub-system to be co-determined; the differences in the percentage of variance explained are quite small on each side of the triangle. Thus it would appear that the actions of the nations in each dyad have a similar (or equal) effect on its partner in the dyad. The differences in behavior explained ranges from four to seven percent and is not substantial enough to warrant assumptions of asymmetric linkages. The arrows indicate the direction of behavior which is being predicted.

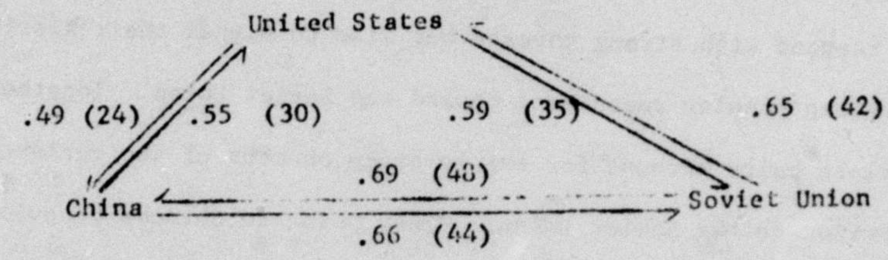


Figure 4. Strength of Linkages in the Triangular Sub-System[7]

Let us now consider the findings for specific behavioral strategies within each dyad. The first canonical analysis was for the behavior of China to the Soviet Union. In this case, we find two specific relationships which merit close attention as they represent correlations between patterns of .99 and .96 -- the first and second variate pairs respectively. With the first variate pair there is a strong relationship between the amount of official military violence China sends to the Soviet Union and the amount of military violence it receives from the Soviet Union. At the same time, there seems to be little or no relationship between China's past and present military violence behavior to the Soviet Union. Thus, it appears that when

---

[7] The numbers enclosed in parentheses represent the percentage of variance in common between the two matrices M and N. It therefore delineates the percentage of variance in behavior which is explained by reciprocity and inertia.

it is confronted by official military violence from the Soviet Union, China is likely to reciprocate in kind, but not likely to continue such behavior over time. The second relationship indicates the use of a slightly more complex behavioral strategy by the Chinese. Specifically, this second variate pair suggests that when confronted by strong threat from the Soviet Union and by the absence of Soviet activity on the two conflict dimensions, unclassified negative acts and boycotts or aid to other nations,[8] the Chinese tend not only to respond with strong threats but also to signal their hostility by demonstrating popular resentment toward the Soviet Union. Together, these two variate pairs account for thirty-seven percent of the variance in China's behavior to the Soviet Union.[9] They point to China's behavior to the Soviet Union as being largely a **function of the conflict behavior received from the** Soviet Union (reciprocity) rather than as a product of some set of strategies based upon prior Chinese actions (inertia).

In the analysis of the reverse dyad (the Soviet Union's behavior toward China), reciprocity again is found to have a major role in accounting for the conflict behavior sent by the actor nation in the dyad. This is clearly evidenced with the first variate pair which reveals a strong relationship between the military conflict behavior the Soviets direct at China and the military conflict behavior they receive from China. In particular, it appears that when confronted by official military violence from the Chinese ,

---

[8]By other object nations, we refer to those nations which are hostile to the object nation. In the case of China, this refers to a nation such as India.

[9]We have presented two different percentage figures in this respect. The first set referred to the percent overlap in the two matrices under consideration and was calculated by squaring the trace correlation. The percent referred to in the current discussion refers to the specific percentage or variation in one nation's behavior which is accounted for by inertia and reciprocity.

the Soviet Union will more than likely reciprocate by directing official military violence toward China. As in the analysis above, there seems to be little or no relationship between past and present Soviet behavior to China on this conflict dimension. With the second variate pair, however, prior Soviet behavior (inertia), does appear to play an important part in explaining Soviet actions to China. Specifically, this refers to those cases where (1) the Soviets engaged in boycotts of the Chinese and aid to other nations who are hostile to China in the previous time period, (2) the Soviet Union is now confronted by the same type of conflict behavior from China, and (3) there is and absence of a strong threat from the Chinese. This second relationship suggests that in such cases the Soviet Union will tend to escalate the conflict behavior it sends to China in the current period with the addition of unclassified negative acts. The importance of prior Soviet behavior in its relations with China is even more clearly portrayed in the third variate pair. Here there is a strong relationship between the unclassified negative acts the Soviets direct at China with prior Soviet unclassified negative acts and warning and defensive acts. It would thus appear that the Soviets tend to show strength (warning and defensive acts) and then off in the next period by reducing their behavior to negative acts, awaiting China's response.

Turning to the relations between China and the United States, the third analysis focuses upon China's behavior to the United States. Three specific relationships deserve close attention. In the first case, warning and defensive acts sent in the previous period affect the combination of threats and diplomatic conflict that the Chinese send in the present period. More precisely, this first relationship suggests that when faced with the lack of

a discernable pattern of American response to warning and defensive acts by the Chinese in the previous period, China is likely to renew its hostility to the United States by directing negative communications and diplomatic sanctions at the United States as well as continuing its previous actions. A similar attempt to seize the initiative in the conflict exchanges between these two nations is found in the second relationship. In this case, Chinese official military violence toward the United States does not appear to be related to either prior Chinese actions to the United States or to the actions China receives from the United States. The relationship delineated in the third variate pair suggests a retreat by the Chinese in their hostility to the United States when faced with intense conflict from the United States. Having engaged in diplomatic conflict aimed at the U.S. in the previous period and being currently faced with military violence from the U.S., the Chinese can be expected to "back down." This concern for avoiding any direct military confrontation with the United States has been observed previously; "...the Chinese seem to have attached the highest priority to the task of avoiding a direct military clash with the United States that could lead to a nuclear war." (Halperin, 1965, P. 13).

Examining the other side of the coin -- the United States' behavior to China -- three patterns of relationship seem to emerge. In the first case, the United States appears to shift its hostility toward China, over time, from the area of diplomatic sanctions to that of unofficial violence when there is an absence of any distinguishable pattern of Chinese hostility being sent to the United States. Put another way, when there is a lull in the hostility received from the Chinese, the United States tends to take

this opportunity to de-escalate its hostility toward China. With the second and third variate pairs, we find that the actions the United States send to the Chinese are directly related to the pattern of conflict behaviors received from China. Specifically, the second relationship posits that when it is confronted by strong threat, the United States will respond with strong threat toward the Chinese, A similar "tit-for-tat" relationship is expressed in the third variate pair: when it receives official military violence from China, the United States can be expected to reciprocate in kind. This strategy is the direct opposite of that adopted by the Chinese as noted above.

This brings us to the final set of dyads analyzed -- the relations between the United States and the Soviet Union. Considering the Soviet Union's behavior to the United States, the patterns of relationships delineated for this dyad suggest a tendency on the part of the Soviet Union to escalate the conflicts between the two nations. That is, it appears that the specific behavioral stragegies employed by the Soviet Union involve not only a response to the particular type of conflict behavior it receives, but also punitive measures. We see with the first variate pair that when it is confronted by strong threat from the United States -- and when it did not direct acts of official military violence at the U.S. in the preceding period -- the Soviet Union can be expected to reciprocate with strong threat combined with expulsions and recalls of diplomatic personnel. The Soviet Union thus seems to be saying to the United States: if you send this particular type of conflict behavior, I will not only respond in kind, but I will punish you for that action with this action.

Soviet escalation of the hostilities it directs at the United States

is even more dramatically portrayed in the second variate pair. Here we find that having restricted the expression of public resentment (unofficial violence) toward the United States in the previous period, the Soviet Union tends to direct acts of official military violence at the U.S. when the hostility it receives from the United States is distinguished by verbal conflict alone. In contrast, when the hostility received from the U.S. is distinguished not only by verbal conflict but also by an absence of official military violence, the Soviets do not resort to official military violence. Rather, the Soviet Union can be expected in these instances to reciprocate in kind. What this seems to suggest is that the reliance on official military violence in the Soviet response to U.S. hostility reflects a strategy of "hitting" unexpectedly to secure some immediate advantage vis-a-vis the United States, to seize the initiative in the Soviets' conflictual relations with the United States.

The final relationship in this system of Soviet strategies further points to the apparent tendency of the Soviet Union to escalate the conflicts between it and the United States. In the absence of any distinguishable response by the United States to prior negative communications from the Soviet Union, the Soviets are likely to escalate their hostility toward the United States by expelling American diplomatic personnel and recalling its own diplomatic personnel.

Whereas Soviet behavior to the United States seems to entail the escalation of hostilities, the United States' behavior to the Soviet Union appears to be characterized by the attempt to de-escalate these hostilities. More precisely, it appears that the United States can be expected to confine itself

to a set of behavioral strategies designed to, at most, reciprocate the type of conflict behavior it receives. With the first variate pair we find that when it receives both strong threat and diplomatic conflict (expulsions and recalls of diplomatic personnel) from the Soviet Union, the United States is likely to direct only strong threat towards the Soviets. The apparent attempt to de-escalate the conflicts between these two nations is more clearly seen in the second and fourth variate pairs. In the former case, the United States' behavior to the Soviet Union incorporates not only a reciprocal response to the amount of negatiave communications received but also an absence of military violence directed at the Soviets. The latter case suggests that if faced with Soviet-instigated reductions in relations between these two nations, the United States will tend to avoid any display of public resentment toward the Soviet Union. Taken together, the relationships revealed in these variate pairs point to a set of strategies which attempt to keep open the door to a possible rapprochement while seeking to effectively deal with the specific conflict situation encountered.

On the whole, the nations in this triangle appear to be closely linked by the forces of inertia and reciprocity. A good deal of the conflict behaviors between any two of these nations was accounted for by one or both of these forces. As to the specific behavioral strategies employed by each nation, it seems that these are largely determined by the nature of the situation faced. Where the situation encountered involves high threat to the actor nation(i.e., where it receives warning and defensive acts and/or official military violence), the tendency appears to be that the actor nation will reciprocate in kind. Thus, the actor nation is likely to disregard existing

strategies based on prior experiences; the three nations appear to be unable to cope with these high threat situations with their existing behavior (inertia). The exception to this appears with China's behavior to the United States in which high levels of threat received from the United States seem to result in the Chinese backing down. In contrast, in low threat situations inertia becomes the governing force. In such instances, both the Soviets and the Chinese appear to take advantage of the situation to escalate their hostilities toward their respective opponents. Only with the United States' actions do we find an indication of an attempt to de-escalate the hostilities in the triangle.

The Effects of Third Parties and the Relations Between Dyads

Returning to the introduction, the possibility that each of the three nations in our analysis takes into consideration the actions of both of the other parties and that it might also coordinate its actions toward both was developed. To this point the analysis has taken the perspective that the exchanges between two nations were a function of policy inertia and reciprocity to the actions of the object nation. This section attempts to explain the over- or under-responses to inertia and reciprocity by resorting to the other actions taking place in the triangle at that point in time.

Equations (4) formalized the impact of the indirect effects. Operationally, the residuals in the canonicals reported in the analysis immediately preceding this were regressed upon the total amount of conflict sent in a given month between the four indirect relationships. Thus, in the case where the United States' behavior to the Soviet Union was analyzed, for example, its behavioral residuals from the above section were regressed upon the total conflict behavior from the Soviet Union to China, China to the Soviet Union, China to the United

States to China. Canonical analysis was again employed in this analysis. The choice of canonical analysis is governed again by our expectations that combinations of actions sent in the direct relationships are interrelated with combinations of dyads' actions in the indirect set of relations.

The canonical results are presented in Tables 9 through 14. In each case the overlaps between the over-and-under action of an actor to an object and the conflict behavior among indirect links of the triangle is not extremely large. On the other hand, specific strategies within each of these relations do point to strong relationships. It is the first and second canonical variate pairs which demonstrate these marked findings.

The first analysis was for Soviet over-and-under response to the United States. Here, it is American hostility toward China and Chinese hostility toward the United States which affected Soviet over-and-under response to the United States. The relationships between the Chinese and the Soviets do not seem important in explaining Soviet behavior to the United States. With the first variate pair, it appears that when the Chinsese are sending hostile words and deeds to the United States and the United States is relatively silent, the Soviets tend to overact in negative communications, diplomatic conflict, and violence aimed at governmental property, but to under-act in violence associated with U.S. personnel. This pattern of Soviet over-and-under response suggests that when the Chinese are engaged in hostilities aimed at the United States, the Soviets join in this activity, protesting loudly but not attempting to physically hurt the United States or its personnel. Put another way, the Soviet Union appears to provide only token support for Chinese actions toward the United State. The second variate pair indicates that when the U. S. is

involved in directing conflict at the Chinese, the Soviets are likely to over-respond in negative communications, official military violence, and negative acts (unclassified). At the same time, the Soviets tend to under-respond with unofficial violence aimed at American government property. Thus the Soviet Union appears to be more vehement in its actions toward the United States than might normally be expected when the U.S. is engaged in hostilities aimed at the Chinese. Considering the relationships expressed in these two variate pairs jointly, there seems to have been a protective mechanism at work during the period analyzed, with the Soviet Union playing the role of protector in Chinese conflict with the U.S.

Soviet actions to China not accounted for by inertia and reciprocity present a somewhat more complex picture (see Table 10). In the preceding case, it was noted that when the Chinese are actively hostile to the U.S., the Soviet Union provides at least token support for Chinese actions by acting against the United States. In the present case, it appears that such a situation in turn, has an important impact on the Soviet's behavior to China. When the Chinese are engaged in hostilities with the United States, the Soviets are also emitting hostile acts to the U.S.. Missing from that analysis, however, is the fact that the Soviets tend to over-act toward the Chinese with regard to official military violence and to under-act with regard to unofficial violence against Chinese government property. Thus it appears that in periods of Sino-American difficulties, the Soviet Union attempts to take advantage of China's involvement with the United States. It may be the case that the Soviets are trying to gain some territorial concessions or to solidify their positions with regard to border disputes with the Chinese.

Joining these two Soviet behaviors, it would appear that in periods of Sino-American difficulties the Soviets adopt a two-pronged policy. With this policy, the Soviets attempt to take advantage of Chinese involvement with the United States to protect or to better their position vis-a-vis the Chinese. In such instances, the Soviets apparently seek to preserve, at least superficially, some semblance of a united front against the United States by expressing hostility towards the U.S. This hostility towards the United States seems to be more marked when the American engage in sending hostile acts to China. At the same time, however, the Soviets tend to take advantage of these difficulties by acting against the Chinese. In a sense, the Soviet startegy resembles an end-around play in football where the play involves a feint in one direction ((Soviet hostility to the U.S.) and then a sweep around the opposite end (Soviet military actions against the Chinese).

Turning to the Chinese activities, the first analysis is of China's direct relations with the United States. In this case, the direct relationships are affected by Chinese actions to the Soviet Union and by the actions of the United States to the Soviet Union. Thus, when both the Chinese and the United States are sending hostile messages or deeds to the Soviet Union, the Chinese are exhibiting more than normal amounts of boycotts and embargoes, and diplomatic conflict activities targeted to the United States, and are underacting in terms of unofficial violence aimed at government property of the United States. On the other hand, when the Chinese are having difficulties with the Soviet Union, (i.e., when the Chinese are both sending and receiving hostile acts from the Soviet Union), they are definitely under-acting toward the United States with regard to both unofficial violence and negative sanctions

surrounding the suspension and reduction of diplomatic relationships. The Chinese appear to have little time for interactions with the United States when they are undergoing real difficulties with the Soviet Union. It should be remembered that the Chinese have increasingly come to see their interactions with the Soviet Union as being potentially more dangerous and thus more salient to them than their interactions with the United States.

With regard to Chinese direct relations with the Soviet Union, the same basic pattern of relationships seems to hold. (Table 12). When the Chinese are actively involved with the United States in hostilities, two patterns of relationship emerge. In the one case, the Chinese show a definite tendency to under-act toward the Soviets in terms of unofficial violence and warning and defensive acts when there is trouble with the United States. In the second case, we again find that in the face of difficulties with the United States, the Chinese also appear to over-act with regard to unclassified negative acts. This apparent break in the suggested pattern of Chinese disengagement with one nation while engaged with the other may be explained, in part, by the fact that the Soviets are directing acts of official military violence at the Chinese in similar situations (i.e., when the Chinese are actively involved with the U.S.). On the whole, however, the Chinese still seem to prefer not to engage both the Soviet Union and the United States at the same time -- when they are engaged with both opponents, the Chinese tend to limit their involvement with one of them to "low threat" actions.

The final set of relationships deals with the United States' direct relations with the Soviet Union and the Chinese Peoples' Republic respectively. Turning first to the U.S. direct relations with the Soviet Union (Table 13),

it appears that when the Chinese are hostile towards both the United States and the Soviet Union, the United States follows a policy designed to ease the tensions in the triangle. If the Chinese send hostile actions to the United States, the U.S. over-acts with regard to the negative messages it directs at the Soviet Union. In connection with Chinese hostilities toward the Soviet Union, the United States under-acts toward the Soviet Union with regard to expulsions and recalls of diplomatic personnel, and with regard to unofficial violence against Soviet government property. Thus it would appear that in periods of Sino-Soviet difficulties, the United States refrains from adding to the Soviets' difficulties, and seeks to take advantage of this situation to reduce the hostilities between the Soviet Union and the United States. On the other hand, the U. S. is likely to "protest" to the Soviet Union when the Chinese are hostile towards the United States. There is another strong relationship between U.S. actions towards the Soviet Union and Chinese hostility to both sides. In this case, the United States shows a strong tendency to a avoid using official military violence or warning and defensive acts aimed at the Soviet Union. It thus appears that the United States prefers prudence when the relations in this triangle become clouded and potentially dangerous.

Examining United States actions toward the Chinese Peoples' Republic, there appears to be two patterns or strategies of action. In connection with U.S. hostilities aimed at the Soviet Union, the United States tends to suspend or reduce relationships to the Chinese and to over-respond with unofficial violence aimed at government property of the Chinese. Secondly, the indirect effects of Chinese hostility to the Soviet Union and, in turn, Soviet hostility to the United States seems to be that the United States will under-act with

regard to both diplomatic conflict and warning and defensive acts. At the same time, the U.S. is likely to increase the unofficial violence it directs at Chinese government property. The United States thus appears to be attempting to balance the relationships in the triangle. More precisely, it appears that the United States is seeking to balance this triangle by alleviating the tension, or hostility in an already dangerous period or by reducing its normal levels of conflict behavior.

In sum, these findings reveal that both the United States and the Soviet Union show at least one pattern in their direct relationships to the Chinese which is an attempt to coordinate hostilities to two nations at one time. However, only the United States appears to attempt to balance the relationships with the Chinese being governed in part by Soviet action to the United States. On the other hand, the Soviet Union demonstrated the only attempt at protection or support in these relationships when it over-responded to the United States in periods of U.S. hostilities aimed at the Chinese. As mentioned previously, the Chinese showed a clear preference in engaging in hostilities with only one of its opponents at a time, reducing its relationships with the other one (limitedly at least) in both cases.

Conclusions

The foreign policy exchanges between the United States, the Soviet Union, and China are closely interlocked. The variation in the conflict behavior between any two of these nations was assumed to be largely accounted for by the direct effects of the object nation. As the findings in fact indicated, both bureaucratic inertia and reciprocity account for a considerable amount of the variation in conflict behavior. It was also suggested that in considering

the exchanges between any two of the three nations, we must additionally consider what is happening in the other parts of the triangular system. Thus, the indirect effects of the other dyads upon the choice of an actor's behavior were examined, with the result that these indirect effects were found to add considerably to our ability to explain the specific strategies employed by each actor nation. Generally speaking, the combination of direct and indirect effects accounted for a sizable portion of the variation in the behavior between nations in each dyad in the triangle. As Table 15 indicates, approximately fifty percent of the variation in the foreign policy exchanges between the three nations was accounted for by this combination of direct and indirect effects.

But what of the fifty or so percent of the variation left unexplained? Assuming that this unexplained variation is the result of stochastic rather than measurement error, what other factors must we then consider in our attempt to understand the nature of the foreign policy linkages between the three nations. One such factor might be the amount of uncertainty each actor has about the other nations' intentions. In order to know the appropriate response to make an object nation, the decision makers of the actor nation must be able to understand clearly and unambiguously the messages which they receive from that object. But these decision makers may be confronted by a multitude of messages of varying types at any one time. In periods where the probability of each of the different types of messages being received is equal, the decision makers find themselves in a situation of little information and of high uncertainty as to the object's intentions. We would expect that these periods of high uncertainty would then have important implications for how the actor would respond to the object. The

question of the impact of uncertainty on the response of nations has been approached, most notably by McClelland (1965, 1968) and Phillips and Crain(1972). McClelland's work, for example, has shown that relative uncertainty values above a certain high level, signal the threshold of a crisis. Phillips and Crain found that in periods of relative uncertainty below this threshold level, the higher the relative uncertainty is, the more reciprocity is the response. With regard to the sub-system considered here, the problem of relative uncertainty is particularly important considering the frequency of occurrence of crises in the relations between the three nations. In particular, we need to consider the impact of high relative uncertainty (i.e., that above McClelland's threshold level) on the response of these three nations.

The foreign policy exchanges between the three nations should not be considered as being governed by the identical restraints placed upon them through the parameters of inertia and reciprocity, however. Not only must the decision makers in these nations deal with pressures placed upon them by the other two nations in the triangle, but they must also cope with internal forces which may serve to constrain their choice of foreign policy actions. Chinese foreign policy, for example, was significantly (although temporarily) disrupted by the events of the Cultural Revolution. Moreover, the domestic character of the three nations differ in a number of important ways. As a result, we might expect that not only will domestic events influence each nation's actions and limit its possible activities, but also that the impact of these domestic events will vary from one nation to the next. Unfortunately the manner in which domestic events influence foreign policy has not been well established to date. Yet we do suggest the need to

consider them (as well as the problem of uncertainty) as perhaps controlling the size of the unexplained variation of the relationships between the United States, the Soviet Union, and China. Initial work has shown that this approach is promising (Phillips, 1973).

BIBLIOGRAPHY

Ashby, W. Ross, 1952, Design for a Brain, London: Chapman & Hall, Ltd.

Aspaturian, Vernon V., 1968, "Foreign Policy Perspectives in the Sixties in Alexander Dallin and Thomas B. Larsen (eds.) Soviet Politics Since Khruschev, Englewood Cliffs, N.J.: Prentice Hall, Inc.

Bartos, Otomar J., 1966, "Concession-Making in Experimental Negotiations", in Joseph Berger, Morris Zelditch Jr., and Bo Anderson Sociological Theories in Progress, New York: Houghton Mifflin.

Boulding, Kenneth, 1962, Conflict and Defense: A General Theory, New York: Harper and Row.

Deutsch, Karl, 1966, "External Influences on the Internal Behavior of States", in R. Barry Farrel (ed.) Approaches to Comparative and International Politics, Evanston: Northwestern University Press.

Dinerstein, Herbert S., 1968, Fifty Years of Soviet Foreign Policy, Baltimore: Johns Hopkins Press.

________________, 1971, "The Soviet Union and China", in Steven L. Spiegel and Kenneth N. Waltz (eds.) Conflict in World Politics, Cambdridge, Mass.: Winthrop Publishers, Inc.

Friedman, Edward, 1971, "The Unites States and China", in Steven L. Speigel and Kenneth N. Waltz (eds.) Conflict in World Politics, Cambdridge, Mass.: Winthrop Publishers, Ind.

Hall, Dennis, and R. J. Rummel, 1969, "The Dynamics of Dyadic Foreign Conflict Behavior, 1955 to 1963", Dimensionality of Nations Research Report No. 16, Honolulu: University of Hawaii.

Halperin, Morton H., 1970, Bureaucratic Politics and Foreign Policy, Washington: The Brookings Institute.

________________, 1965, China and the Bomb, New York: Praeger.

Herz, John H., 1959, International Politics in the Atomic Age, New York:

__________, 1957, "Rise and Demise of the Territorial State", World Poltiics, Vol, IX.

Kaplan, Morton, 1970, "Changes in United States Perspectives on the Soviet Union and Detente", in Morton Kaplan (ed.), Great Issues of International Politics, Chicago: Aldine Publishing Co.

Lowenthal, Richard, 1968, "Communist China's Foreign Policy" in Tang Tsou (ed.) China in Crisis, Vol. II China's Policies in Asia and America's Alternative, Chicago: University of Chicago Press.

__________, 1968, "The Soviet Union in the Post-Revolutionary Era: An Overview" in Alexander Dallin and Thomas B. Larson, Soviet Politics Since Khruschev, Englewood Cliffs, N.J.: Prentice-Hall, Inc.

McClelland, Charles A., 1968, "Access to Berlin: The Quantity and Variety of Events", in J. David Singer (ed.) Quantitative International Politics: Insights and Evidence, New York: Free Press.

McClelland, Charles A., 1966, Theory and the International System, New York: The Macmillan Company.

__________, and Gary D. Hoggard, 1969, "Conflict Patterns in the Interactions Among Nations", in James N, Rosenau (ed.) International Politics and Foreign Policy: A Reader in Research and Theory, New York : Free Press

__________, et al, 1965, "The Communist Chinese Performance in Crisis and Non-Crises: Quantitative Studies of the Taiwan Straits Confrontation, 1950-1964" China Lake, California: U.S. Naval Ordinace Test Station, NROTS TP 4138.

Moms, Bernard S., 1968, International Communism and American Policy, New York: Albertson Press.

Morrison, Donald F., 1967, Multivariate Statistical Methods, New York: McGraw-Hill Book Co.

Oliva, Gary and R. J. Rummel, 1967, "Foreign Conflict Patterns and Types for 1963" Dimensionality of Nations Research Report No. 22, Honolulu: University of Hawaii.

Phillips, Warren R., 1972, "Dynamic Foreign Policy Interactions", Columbus, Ohio State University (Mimeo).

__________, 1969, "Dynamic Patterns of International Conflict", Dimensionality of Nations Research Report No. 33, Honolulu: University of Hawaii.

__________, 1972, "Introduction to Canonical Analysis", Columbus, Ohio State Univwrsity. (Mimeo).

__________ and Robert C. Crain, 1972, "Dynamic Foreign Policy Interactions: Reciprocity and Uncertainty in Foreign Policy", Columbus, Ohio State University. (Mimeo).

Rosenau, James N., 1969, Linkage Politics, New York: Free Press

Rummel, Rudolph J., 1966, "A Foreign Conflict Code Sheet", World Politics, Vol. XVIII.

Tanter, Raymond , 1972, "International System and Foreign Policy Approaches: Implications for Conflict Modeling and Management", World Politics, XXIV.

Tsou, Tang, 1965, "Peking and Peaceful Coexistence", in Robert A. Goldwin. Beyond the Cold War. Chicago: Rand McNally & Co.

Zagoria, Donald, 1968, "The Strategic Debate in Peking", in Tang Tsou, China in Crisis, Vol. IX: China's Policies in Asia and American's Alternative Chicago: University of Chicago Press.

Zimmerman, Willaim, 1968, "Soviet Perceptions of the United States " in Alexander Dallin and Thomas B. Larson (eds.) Soviet Politics Since Khr chev. Englewood Cliffs, N.J.: Prentice-Hall, Inc.

______________, 1969, Soviet Perspectives on International Relations, 1956-1967, Princeton: Princeton University Press.

______________, 1971, "The Soviet Union" in Steven L. Spiegel and Kenneth N. Waltz (eds.) Conflict in World Politics, Cambdridge, Mass: Winthrop Publishers, Inc.

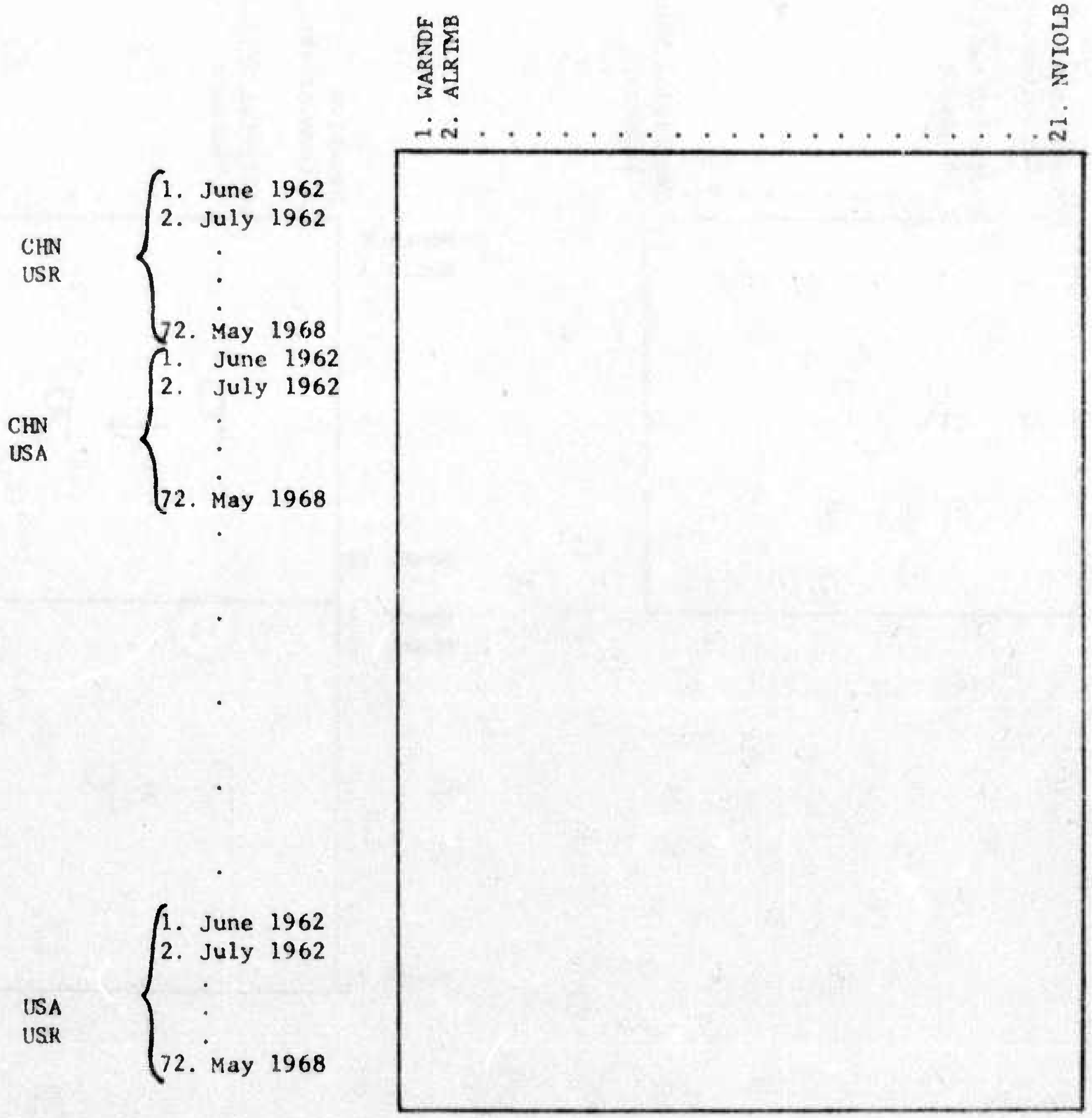


Figure 2. Organization of the Super-P matrix.

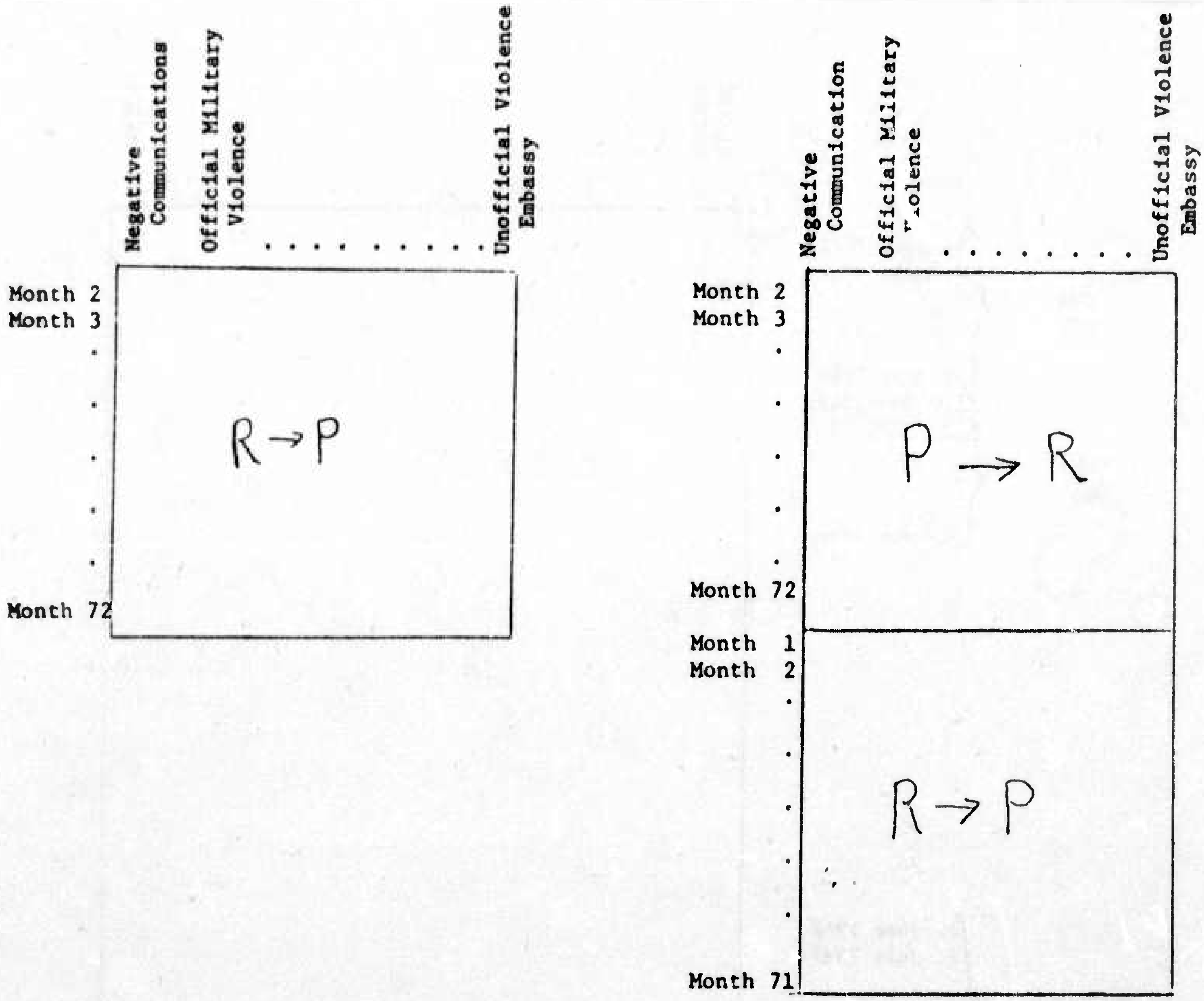


Figure 3. Organization of Factor Scores
from Factor Analysis

Table 1
DON Dyadic Foreign Conflict Variables Used*

Primary Category	Variable No.	Code		Variable
Warning and Defensive Acts	1	WARNDF	-	Military Maneuvers or Troop Movements
	2	ALRTMB	-	Alerts, Mobilizations, and Military Movements
Official Acts of Violence	3	PLNVIL	-	Planned Violent Acts
	4	WARACT	-	Overt Violence
	5	DAYVIL	-	Days of Violence
Negative Sanctions	6	NEGACT	-	Negative Behavior Acts
	7	UNCNEG	-	Unclassified Negative Acts
	8	SEVDPR	-	Severances or Suspensions of Diplomatic Relations
	9	EXPREC	-	Expulsion or Recall of Diplomatic Officials
	10	BCOTIEM	-	Boycott or Embargo
	11	AIDREB	-	Air to Rebellious Group and to Object's Violent Enemy
Negative Communications	12	NEGCOM	-	Negative Communications
	13	WRTCOM	-	Written Negative Communications
	14	ORLCOM	-	Oral Negative Communications
	15	ACCUSN	-	Accusations
	16	PROTST	-	Protests
	17	MINTHM	-	Minor themes-warning; threat; denunciation; accusation; provocation; violent action
Unofficial Violence	18	UNOFVL	-	Unofficial Planned Violence
	19	ATKEMB	-	Attacks on Embassy
	20	ATKPER	-	Attacks on Official Property Other Than Embassy and on Personnel
Non-violent Demonstrations	21	NVIOLB	-	Non-violent behavior**

* Primary code sheet categories are separated by solid lines. Variables 1-17 are Official Acts; variables 18-21 are Unofficial Acts.

** Mainly including nonviolent anti-foreign demonstrations

Table 2

Annotated Orthogonally Rotated Factor Matrix*
The Patterns of Conflict Exchanges in the Soviet - U.S. - China
Sub-System, 1962-1968

Communality: Proportion of variation of each variable involved in the patterns; sum of squared factor loadings

Separate patterns of relationships between the variables

Loading: degree and direction of relationship of the variables with the pattern

Conflict Variables	H-SQR	1	2	3	4	5	6	7	8
12. NEGCOM	0.966	0.97							
13. WRTCOM	0.820	0.88							
14. ORLCOM	0.631	0.77							
15. ACCUSN	0.856	0.91							
17. MINTHM	0.600	0.69							
3. PLNVIL	0.948		0.97						
5. WARACT	0.950		0.96						
6. DAYVIL	0.969		0.98						
18. UNOFVL	0.999			-0.71					0.71
20. ATKPER	0.991			-0.99					
1. WARNDF	0.866				-0.93				
2. ALRTMB	0.877				-0.93				
6. NEGACT	0.943					0.85			
7. UNCNEG	0.724					0.81			
10. BCOTEM	0.636						0.75		
11. AIDREB	.599						0.76		
8. SEVDPR	0.637							0.76	
9. EXPREC	0.535							-0.51	
19. ATKEMB	0.987								0.99
16. PROTST	0.266								
21. NVIOLB	0.440								
PERCENT OF TOTAL VARIANCE	77.34	18.55	13.79	7.18	9.41	8.58	7.38	5.29	7.16

Percent of variation among all the variables involved in the conflict exchange factors, or patterns.

Percent of variation among all conflict variables involved in the particular factors, or patterns.

*For purposes of clarity, only the highest loadings of the 21 conflict variables have been displayed here.

Table 3

Annotated Canonical Structure Matrix*
Chinese Behavior towards the Soviet Union

Communality: proportion of variation of each dimension of inertia and reciprocity involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the dimensions.

Canonical Structure Matrix

Behavioral Dimensions of Inertia and Reciprocity		R-SQR	CANONICAL VARIATES 1	2
INERTIA	Negative Communications	0.471		
	Official Military Violence	0.184		
	Unofficial Violence - Personnel	0.581		
	Warning and Defensive Acts	0.914		
	Unclassified Negative Acts	0.641		
	Boycotts & Embargoes/Aid to Others	0.428		
	Diplomatic Conflict	0.227		
	Unofficial Violence - Embassy	0.591		
RECIPROCITY	Negative Communications	0.726		
	Official Military Violence	0.833	0.726	
	Unofficial Violence - Personnel	0.508		
	Warning and Defensive Acts	0.641		0.629
	Unclassified Negative Acts	0.851		-0.705
	Boycotts & Embargoes/Aid to Others	0.755		-0.662
	Diplomatic Conflict	0.714		-0.419
	Unofficial Violence - Embassy	0.412	-0.404	

Proportion: Percent of variation among all the dimensions involved in the variates.

Loading: degree and direction of relationship of the dimensions with this pattern.

Proportion of Inertia and Reciprocity Dimensions Variance	59.355	7.036	14.251

Trace Correlations: general overlap between the dimensions of inertia and reciprocity and the dimensions of Chinese behavior to the Soviet Union.

Percent of variation among all dimensions involved in the particular variates.

Canonical Correlation	0.639	0.979	0.958

Canonical correlation: the statistical dependence between each matched pair of variates.

Dimensions of Chinese Behavior to the Soviet Union			
Negative Communications	1.000		
Official Military Violence	1.000	0.879	
Unofficial Violence - Personnel	1.000		0.725
Warning and Defensive Acts	1.000		0.836
Unclassified Negative Acts	1.000		
Boycotts & Embargoes/Aid to Others	1.000		0.525
Diplomatic Conflict	1.000		
Unofficial Violence - Embassy	1.300		0.605

Percent of variation among all the dimensions involved in these variates.

Percent of variation among all dimensions involved in the particular variate.

Proportion of Chinese Behavior Variance	100.000	10.464	26.978

Percent of variation among all the dimensions involved in the variates.

Percent of variation among all the dimensions involved in the particular variate pairs.

Proportion of Total Variance	72.904	8.165	18.493

* For purposes of clarity, only those canonical variate pairs have been displayed here which point to strong relationships between variate pairs, and which are discussed in the text. As such, the sum of the percent of variation for each variate will not equal the percent of variation among all dimensions involved in the variates. Additionally, only the highest loadings on the canonical variates have been displayed.

Table 4

Annotated Canonical Structure Matrix*
Soviet Behavior Towards China

Communality: proportion of variations of each dimension of inertia and reciprocity involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the dimensions.

Canonical Structure Matrix

Behavioral Dimensions of Inertia and Reciprocity		H-SQR	CANONICAL VARIATES 1	2	3
INERTIA	Negative Communications	0.463			
	Official Military Violence	0.172			
	Unofficial Violence - Personnel	0.324			
	Warning and Defensive Acts	0.830			0.578
	Unclassified Negative Acts	0.774			-0.578
	Boycotts & Embargoes/Aid to Others	0.910		0.764	
	Diplomatic Conflict	0.725			
	Unofficial Violence - Embassy	0.354			
RECIPROCITY	Negative Communications	0.189			
	Official Military Violence	0.887	-0.914		
	Unofficial Violence - Personnel	0.720		-0.678	
	Warning and Defensive Acts	0.859		-0.883	
	Unclassified Negative Acts	0.401			
	Boycotts & Embargoes/Aid to Others	0.706		0.504	-0.492
	Diplomatic Conflict	0.451			
	Unofficial Violence - Embassy	0.645		-0.557	
Proportion of Inertia and Reciprocity Dimensions Variance		58.816	5.740	19.055	9.896
Canonical Correlation		0.693	0.989	0.933	0.790
Dimensions of Soviet Behavior to China	Negative Communications	1.000			
	Official Military Violence	1.000	-0.767		
	Unofficial Violence - Personnel	1.000		-0.423	
	Warning and Defensive Acts	1.000		-0.662	
	Unclassified Negative Acts	1.000		0.752	-0.505
	Boycotts and Embargoes/Aid to Others	1.000		0.652	
	Diplomatic Conflict	1.000		0.425	0.455
	Unofficial Violence - Embassy	1.000			
Proportion of Chinese Behavior Variance		100.000	13.062	25.290	12.787
Proportion of Total Variance		72.544	8.180	21.174	10.693

Proportion: Percent of variation among all the dimensions involved in the variates.

Loading: degree and direction of relationship of the dimensions with this pattern.

Trace Correlations: general overlap between the dimensions of inertia and reciprocity and the dimensions of Chinese behavior in the Soviet Union.

Percent of variation among all dimensions involved in the particular variates.

Canonical correlation: the statistical dependence between each matched pair of variates.

Percent of variation among all the dimensions involved in these variates.

Percent of variation among all dimensions involved in the particular variate.

Percent of variation among all the dimensions involved in the variates.

Percent of variation among all the dimensions involved in the particular variate pairs.

* See footnote, Table 3.

Table 5

Annotated Canonical Structure Matrix*
Chinese Behavior to the United States

Communality: proportion of variations of each dimension of inertia and reciprocity involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the dimensions.

Loading: degree and direction of relationship of the dimensions with this pattern.

Proportion: Percent of variation among all the dimensions involved in the variates.

Percent of variation among all dimensions involved in the particular variate.

Trace Correlations: general overlap between the dimensions of inertia and reciprocity and the dimensions of Chinese behavior to the Soviet Union.

Canonical correlation: the statistical dependence between each matched pair of variates.

Percent of variation among all the dimensions involved in those variates.

Percent of variation among all dimensions involved in the particular variate.

Percent of variation among all the dimensions involved in the variates.

Percent of variation among all the dimensions involved in the particular variate pairs.

Canonical Structure Matrix

			CANONICAL VARIATES	
Behavioral Dimensions of Inertia and Reciprocity	H-SQR	1	2	3
INERTIA				
Negative Communications	0.774			
Official Military Violence	0.421			
Unofficial Violence - Personnel	0.530			
Warning and Defensive Acts	0.775	-0.616		
Unclassified Negative Acts	0.547			0.429
Boycotts and Embargoes/Aid to Others	0.802			-0.641
Diplomatic Conflict	0.521			
Unofficial Violence - Embassy	0.539		0.402	-0.250
RECIPROCITY				
Negative Communications	0.647	0.443		
Official Military Violence	0.882			-0.533
Unofficial Violence - Personnel	0.561			
Warning and Defensive Acts	0.489			
Unclassified Negative Acts	0.560			
Boycotts and Embargoes/Aid to Others	0.259			
Diplomatic Conflict	0.530			
Unofficial Violence - Embassy	0.623			
Proportion of Inertia and Reciprocity Dimensions Variance	59.758	6.701	5.923	10.126
Canonical Correlations	0.548	0.958	0.697	0.662
Dimensions of Chinese Behavior to the United States				
Negative Communications	1.000	0.661		
Official Military Violence	1.000		-0.618	
Unofficial Violence - Personnel	1.000			-0.667
Warning and Defensive Acts	1.000	-0.648		
Unclassified Negative Acts	1.000	-0.414		
Boycotts and Embargoes/Aid to Others	1.000		0.428	
Diplomatic Conflict	1.000	0.753		
Unofficial Violence - Embassy	1.000			-0.405
Proportion of Chinese Behavior Variance	100.000	23.075	12.301	14.515
Proportion of Total Variance	73.172	12.159	8.049	11.589

* See footnote, Table 3.

Table 6

Annotated Canonical Structure Matrix*
United States Behavior to the Chinese

Communality: proportion of variations of each dimension of inertia and reciprocity involved in the patterns; sum of squared factor loadings.

Separate patterns of relationship between the dimensions.

Canonical Structure Matrix		H-SQR	Canonical Variates 1	Canonical Variates 2	Canonical Variates 3
Behavioral Dimensions of Inertia and Reciprocity					
INERTIA	Negative Communications	0.705			0.492
	Official Military Violence	0.440			
	Unofficial Violence - Personnel	0.817		0.444	0.428
	Warning and Defense Acts	0.103			
	Unclassified Negative Acts	0.908	0.900		
	Boycotts and Embargoes/Aid to Others	0.086			
	Diplomatic Conflict	0.504	0.501		
	Unofficial Violence - Embassy	0.734		0.428	
RECIPROCITY	Negative Communications	0.562			0.479
	Official Military Violence	0.930			0.616
	Unofficial Violence - Personnel	0.583			
	Warning and Defensive Acts	0.788		0.704	
	Unclassified Negative Acts	0.635			
	Boycotts and Embargoes/Aid to Others	0.272			
	Diplomatic Conflict	0.712	0.405	-0.442	
	Unofficial Violence - Embassy	0.673			
Proportion of Inertia and Reciprocity Dimensions Variance		59.079	10.046	9.047	10.108
Canonical Correlations		0.492	0.834	0.668	0.585
Dimensions of U.S. Behavior to China					
	Negative Communications	1.000	0.826		
	Official Military Violence	1.000		0.484	0.835
	Unofficial Violence - Personnel	1.000	0.911		
	Warning and Defensive Acts	1.000		0.526	
	Unclassified Negative Acts	1.000			
	Boycotts and Embargoes/Aid to others	1.000			
	Diplomatic Conflict	1.000			-0.416
	Unofficial Violence - Embassy	1.000	0.806		
Proportion of U.S. Behavior Variance		100.000	27.563	8.835	15.059
Proportion of Total Variance		72.721	15.885	8.977	11.759

Loading: degree and direction of relationship of the dimensions with this pattern.

Proportion: Percent of variation among all the dimensions involved in the variates.

Percent of variation among all dimensions involved in the particular variates.

Trace Correlations: general overlap between the dimensions of inertia and reciprocity and the dimensions of Chinese behavior to the Soviet Union.

Canonical correlation: the statistical dependence between each matched pair of variates.

Percent of variation among all the dimensions involved in these variates.

Percent of variation among all dimensions involved in the particular variate.

Percent of variation among all the dimensions involved in the variates.

Percent of variation among all dimensions involved in the particular variate.

* See footnote, Table 3.

Table 7

Annotated Canonical Structure Matrix
Soviet Behavior to the United States

Communality: proportion of variation of each dimension of inertia and reciprocity involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the dimensions.

Canonical Structure Matrix

Behavioral Dimensions of Inertia and Reciprocity	H-SQR	1	2	3	4
Negative Communications	0.772				-0.575
Official Military Violence	0.717	-.0646			
Unofficial Violence - Personnel	0.904		-0.629	0.591	
Warning and Defensive Acts	-0.142				
Unclassified Negative Acts	0.296				
Boycotts and Embargoes/Aid to Others	0.225				
Diplomatic Conflict	0.283				
Unofficial Violence - Embassy	0.413				-0.472
Negative Communications	-0.836		0.636	0.551	
Official Military Violence	0.723		-0.444	-0.584	
Unofficial Violence - Personnel	0.469				
Warning and Defensive Acts	0.989	0.991			
Unclassified Negative Acts	0.622				-0.656
Boycotts and Embar_oes/Aid to Others	0.331				
Diplomatic Conflict	0.519				
Unofficial Violence - Embassy	0.211				

Proportion: Percent of variation among all the dimensions involved in the variates.

Loading: degree and direction of relationship of the dimensions with this pattern.

		1	2	3	4
Proportion of Inertia and Reciprocity Dimensions Variance	52.834	11.277	7.540	8.231	7.924

Percent of variation among all dimensions involved in the particular variates.

Trace Correlation: general overlap between the dimensions of inertia and reciprocity and the dimensions of Chinese behavior to the Soviet Union.

		1	2	3	4
Canonical Correlations	0.652	0.983	0.847	0.758	0.678

Canonical correlation: the statistical dependence between each matched pair of variates.

Dimensions of Soviet Behavior to the United States		1	2	3	4
Negative Communications	1.000		0.438	0.617	
Official Military Violence	1.000		0.677	-0.563	0.473
Unofficial Violence - Personnel	1.000				
Warning and Defensive Acts	1.000	0.894			
Unclassified Negative Acts	1.000				
Boycot§s and Embargoes/Aid to Others	1.000			0.419	
Diplomatic Conflict	1.000	0.524			0.717
Unofficial Violence - Embassy	1.000			0.448	

Percent of variation among all the dimensions involved in these variates.

Percent of variation among all dimensions involved in the particular variate.

		1	2	3	4
Proportion of Soviet Behavior Variance	100.000	16.881	11.109	16.310	9.763

Percent of variation among all the dimensions involved in the variates.

Percent of variation among all the dimensions involved in the particular variate pairs.

		1	2	3	4
Proportion of Total Variance	66.556	12.478	8.756	10.924	8.530

* See footnote, Table 3.

Table 8

Annotated Canonical Structure Matrix
United States Behavior to the Soviet Union

Communality: proportion of variation of each dimension of inertia and reciprocity involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the dimensions.

Loading: degree and direction of relationship of the dimensions with this pattern.

Proportion: Percent of variation among all the dimensions involved in the variates.

Percent of variation among all dimensions involved in the particular variates.

Trace Correlation: general overlap between the dimensions of inertia and reciprocity and the dimensions of Chinese behavior to the Soviet Union.

Canonical correlation: the statistical dependence between each matched pair of variates.

Percent of variation among all the dimensions involved in these variates.

Percent of variation among all dimensions involved in the particular variate pairs.

Percent of variation among all the dimensions involved in the variates.

Percent of variation among all the dimensions involved in the particular variate pairs.

Canonical Structure Matrix	H-SQR	CANONICAL VARIATES 1	2	3	4
Behavioral Dimensions of Inertia and Reciprocity					
INERTIA: Negative Communications	0.682				
Official Military Violence	0.422				
Unofficial Violence - Personnel	0.329				
Warning and Defensive Acts	0.091				
Unclassified Negative Acts	0.765			-0.518	
Boycotts and Embargoes/Aid to Others	0.464				
Diplomatic Conflict	0.307				
Unofficial Violence - Embassy	0.090				
RECIPROCITY: Negative Communications	0.912		0.604	-0.432	
Official Military Violence	0.593				
Unofficial Violence - Personnel	0.531				
Warning and Defensive Acts	0.975	0.895			
Unclassified Negative Acts	0.454				-0.487
Boycotts and Embargoes/Aid to Others	0.484		0.467		
Diplomatic Conflict	0.737	0.502			0.619
Unofficial Violence - Embassy	0.892				
Proportion of Inertia and Reciprocity Variance	54.548	7.720	7.691	6.358	7.620
Canonical Correlation	0.589	0.983	0.829	0.601	0.556
Dimensions of U.S. Behavior to the Soviet Union					
Negative Communications	1.000		0.846		
Official Military Violence	1.000		-0.681		
Unofficial Violence - Personnel	1.000		-0.406		
Warning and Defensive Acts	1.000	0.994			
Unclassified Negative Acts	1.000				-0.710
Boycotts and Embargoes/Aid to Others	1.000				
Diplomatic Conflict	1.000			-0.430	0.627
Unofficial Violence - Embassy	1.000				
Proportion of U.S. Behavior Variance	100.000	16.044	18.187	5.869	12.333
Proportion of Total Variance	69.699	10.495	11.189	6.195	9.191

* See footnote, Table 3.

Table 9

Annotated Canonical Structure Matrix*
Soviet Over- and Under- Action to the United States

Communality: proportion of variation of each dimension of over- and under- actions involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the dimensions

Canonical Structure Matrix

Soviet Over- and Under- Action to the United States	H-SQR	CANONICAL VARIATE 1	2	3	4
Negative Communications	0.936	0.541	-0.415	-0.598	
Official Military Violence	0.360		-0.402		
Unofficial Violence - Personnel	0.[illegible]36	0.428			
Warning and Defensive Acts	0.305				0.402
Unclassified Negative Acts	0.405		-0.412	0.484	
Boycotts and Embargoes/Aid to others	0.832				-0.722
Diplomatic Conflict	0.413	0.458		0.404	
Unofficial Violence - Embassy	0.514	0.413	0.452		

Proportion: percent of variation among all the dimensions involved in the variates.

Loading: degree and direction of relationship of the dimensions with this pattern.

Proportion of Soviet Over- and Under-Action Variance	50.000	12.501	12.499	12.499	12.500

Trace Correlation: general overlap between the dimensions of over- and under- action and the indirect relationships.

Percent of variation among all dimensions involved in the particular variates.

Canonical Correlation	0.350	0.525	0.340	0.273	0.152

Canonical correlation: the statistical dependence between each matched pair of variates.

Indirect Relationships					
USA → CHN	1.000		-0.941		
CHN → USA	1.000	0.922			
USR → CHN	1.000				0.952
CHN → USR	1.000			0.881	

Percent of variation among all the indirect relationships involved in these variates.

Percent of variation among all indirect relationships involved in the particular variate.

Proportion of Indirect Relationships Variance	100.000	24.717	25.124	21.233	28.926

Percent of variation among all dimensions and indirect relationships involved in the variates.

Percent of variation among all the indirect relationships involved in the particular variate pairs

Proportion of Total Variance	66.666	16.573	16.708	15.410	17.975

* For purposes of clarity, only the highest loadings on the canonical variates have been displayed here.

Table 10

Annotated Canonical Structure Matrix*
Soviet Over- and Under- Action to the Chinese

Communality: proportion of variation of each dimensions of over- and under-actions involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the dimensions.

Canonical Structure Matrix

Soviet Over- and Under- Action To China	H-SQR	CANONICAL VARIATES 1	2	3	4
Negative Communication	0.590		0.547		
Official Military Violence	0.512	0.669			
Unofficial Violence - Personnel	0.274				
Warning and Defensive Acts	0.672		-0.485	-0.548	
Unclassified Negative Acts	0.830		0.537		-0.689
Boycotts and Embargoes/Aid to Others	0.134				
Diplomatic Conflict	0.208				
Unofficial Violence - Embassy	0.778	-0.506		-0.534	0.486

Proportion: percent of variation among all the dimensions involved in the variates.

Loading: degree and direction of relationship of the dimensions with this pattern.

	H-SQR	1	2	3	4
Proportion of Soviet Over- and Under- Action	50.000	12.500	12.499	12.500	12.501

Trace Correlation: general overlap between the dimensions of over- and under- action and the indirect relationships.

Percent of variation among all dimensions involved in the particular variates.

	H-SQR	1	2	3	4
Canonical Correlation	0.241	0.382	0.233	0.171	0.053

Canonical correlation: the statistical dependence between each matched pair of variates.

Indirect Relationships	H-SQR	1	2	3	4
CHN → USA	1.000	0.954			
USA → CHN	1.000			0.985	
USA → USR	1.000				0.965
USR → USA	1.000	0.615	0.739		

Percent of variation among all dimensions and indirect relationships involved in the variates.

Percent of variation among all the indirect relationships involved in the particular variate.

	H-SQR	1	2	3	4
Proportion of Indirect Relationship Variance	100.000	32.961	16.438	25.321	25.280

Percent of variation among all dimensions and indirect relationships involved in the variates.

Percent of variation among all the indirect relationships involved in the particular variate pairs.

	H-SQR	1	2	3	4
Proportion of Total Variance	66.667	19.320	13.812	16.774	16.761

* For purposes of clarity, only the highest loadings on the canonical variates have been displayed here.

Table 11

Annotated Canonical Structure Matrix*
Chinese Over- and Under- Action to the United States

Communality: proportion of variation of each dimension of over- and under- action involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the dimensions

Loading: degree and direction of relationship of the dimensions with this pattern.

Proportion: percent of variation among all the dimensions involved in the variates.

Percent of variation among all dimensions involved in the particular variates.

Trace Correlation: general overlap between the dimensions of over- and under- action and the indirect relationships.

Canonical correlation: the statistical dependence between each matched pair of variates.

Percent of variation among all the indirect relationships involved in these variates.

Percent of variation among all indirect relationships involved in the particular variate.

Percent of variation among all dimensions and indirect relationships involved in the variates.

Percent of variation among all the indirect relationships involved in the particular variate pairs.

Canonical Structure Matrix		CANONICAL VARIATES			
Chinese Over- and Under- Action to the United States	H-SQR	1	2	3	4
Negative Communications	0.183				
Official Military Violence	0.232				
Unofficial Violence - Personnel	0.835		0.490	-0.637	
Warning and Defensive Acts	0.060				
Unclassified Negative Acts	0.732				-0.821
Boycotts and Embargoes/Aid to Others	0.416	0.559			
Diplomatic Conflict	0.889	0.487	0.734		
Unofficial Violence	0.653	-0.497		0.598	
Proportion of Chinese Over- and Under- Action Variance	50.000	12.500	12.501	12.499	12.500
Canonical Correlation	0.399	0.551	0.481	0.310	0.081
Indirect Relationships					
CHN → USR	1.000	-0.768	0.497		
USR → CHN	1.000		0.898	0.412	
USA → USR	1.000	-0.528		0.751	
USR → USA	1.000			0.444	0.886
Proportion of Indirect Relationships Variance	100.000	21.946	29.035	25.146	23.873
Proportion of Total Variance	66.667	15.640	18.012	16.715	16.291

* For purposes of clarity, only the highest loadings on the canonical variates have been displayed here.

Table 12

Annotated Canonical Structure Matrix*
Chinese Over- and Under- Action to the Soviet Union

Communality: proportion of variation of each dimension of over- and under-actions involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the dimensions.

Canonical Structure Matrix	H-SQR	CANONICAL VARIATES 1	2	3	4
Chinese Over- and Under- Action to the Soviet Union.					
Negative Communications	0.238				
Official Military Violence	0.780		-0.671	-0.558	
Unofficial Violence - Personnel	0.559	0.404		0.463	-0.424
Warning and Defensive Acts	0.481	0.593			
Unclassified Negative Acts	0.684		0.500	-0.641	
Boycotts and Embargoes/Aid to Others	0.689				-0.756
Diplomatic Conflict	0.125				
Unofficial Violence - Embassy	0.444	0.582			
Proportion of Chinese Over- and Under-Action Variance.	49.998	12.500	12.498	12.500	12.500
Canonical Correlation	0.265	0.347	0.278	0.255	0.1[illegible]1
Indirect Relationships					
CHN→USA	1.000	0.821	-0.518		
USA→CHN	1.000	0.5[illegible]4		0.825	
USA→USR	1.000				0.966
USR→USA	1.000		-0.897		
Proportion of Indirect Relationships Variance	100.000	24.917	27.010	22.224	2[illegible].849
Proportion of Total Variance	66.666	16.639	17.33[illegible]	15.741	16.950

Loading: degree and direction of relationship of the dimensions with this pattern.

Proportion: percent of variation among all the dimensions involved in the variates.

Percent of variation among all dimensions involved in the particular variate.

Trace Correlation: general overlap between the dimensions of over- and under- action and the indirect relationships.

Canonical Correlation: the statistical dependence between each matched pair of variates.

Percent of variation among all the indirect relationships involved in those variates.

Percent of variation among all indirect relationships involved in the particular variate.

Percent of variation among all dimensions and indirect relationships involved in the variates.

Percent of variation among all the indirect relationships involved in the particular variate pairs.

* For the purposes of clarity, only the highest loadings on the canonical variates have been displayed here.

Table 13

Annotated Canonical Structure Matrix*
U.S. Over- and Under- Action to the Soviet Union

Communality: proportion of variation of each dimension of over- and under-actions involved in the patterns; sum of squared factor loadings.

Separate Patterns of relationships between the dimensions.

Canonical Structure Matrix	H-SQR	1	2	3	4
		CANONICAL VARIATES			
United States Over- and Under-Action to the Soviet Union					
Negative Communications	0.701	0.543			
Official Military Violence	0.533		-0.584		
Unofficial Violence - Personnel	0.681			0.780	
Warning and Defensive Acts	0.870		-0.559		-0.728
Unclassified Negative Acts	0.163				
Boycotts and Embargoes/Aid to Others	0.166				
Diplomatic Conflict	0.528	-0.591		0.403	
Unofficial Violence - Embassy	0.359	-0.467			

Loading: degree and direction of relationship of the dimensions with this pattern.

Proportion: percent of variation among all the dimensions involved in the variates.

Proportion of U.S. over- and Under-Action	49.999	12.500	12.501	12.499	12.500

Percent of variation among all dimensions between each matched pair of variates.

Trace Correlation: general overlap between the dimensions of over- and under- action and the indirect relationships

Canonical Correlation	0.378	0.486	0.462	0.269	0.227

Canonical Correlation: the statistical dependence between each matched pair of variates.

Indirect Relationships					
USA → CHN	1.000			-0.780	-0.530
CHN → USA	1.000	-0.525	0.846		
USR → CHN	1.000				0.915
CHN → USR	1.000	0.749	0.564		

Percent of variation among all the indirect relationships involved in these variates.

Percent of variation among all indirect relationships involved in the particular variate.

Proportion of Indirect Relationships Variance	100.000	21.306	28.716	20.416	29.562

Percent of variation among all dimensions and indirect relationships involved in the variates.

Percent of variation among all the indirect relationships involved in the particular variate pairs.

Proportion of Total Variance	66.666	15.435	17.906	15.138	18.187

* For the purposes of clarity, only the highest loadings on the canonical variates have been displayed here.

Table 14

Annotated Canonical Structure Matrix*
U. S. Over- and Under- Action to the Chinese

Communality: proportion of variation of each dimensions of over- and under- actions involved in the patterns; sum of squared factor loadings.

Separate patterns of relationships between the dimensions.

Canonical Structure Matrix

		CANONICAL VARIATES			
U.S. Over- and Under- Action to the Chinese	H-SQR	1	2	3	4
Negative Communications	0.074				
Official Military Violence	0.830			-0.790	
Unofficial Violence - Personnel	0.239				
Warning and Defensive Acts	0.300		0.502		
Unclassified Negative Acts	0.556				-0.740
Boycotts and Embargoes/Aid to Others	0.681			0.563	0.452
Diplomatic Conflict	0.744	0.538	-0.548		
Unofficial Violence - Embassy	0.839	0.638	0.442	0.485	

Proportion: percent of variation among all the dimensions involved in the variates.

Loading: degree and direction of relationship of the dimensions with this pattern.

Proportion of U.S. over- and Under- Action Variance	53.280	12.805	11.988	16.798	11.689

Trace Correlation: general overlap between the dimensions of over- and under- action and the indirect relationships.

Percent of variation among all dimensions involved in the particular variates.

Canonical Correlation	0.339	0.514	0.375	0.182	0.147

Canonical Correlation: the Statistical dependence between each matched pair of variates.

Indirect Relationships					
CHN → USR	1.000		0.635	-0.758	
USR → CHN	1.000				0.936
USA → USR	1.000	-0.825	0.477		
USR → USA	1.000	0.435	0.667	0.567	

Percent of variation among all the indirect relationships involved in these variates.

Percent of variation among all indirect relationships involved in the particular variate.

Proportion of Indirect Relationships Variance	100.000	22.339	26.992	27.194	23.474

Percent of variation among all dimensions and indirect relationships involved in the variates.

Percent of variation among all the indirect relationships involved in the particular variate pairs.

Proportion of Total Variance	68.853	15.983	16.989	20.263	15.617

* For the purposes of clarity, only the highest loadings on the canonical variates have been displayed here.

Table 15
Summary of Amount of Variation
Explained

Direct and Indirect Effects	CHN USR	CHN USA	USR CHN	USR USA	USA CHN	USA USR
Inertia & Reciprocity	43.4	30.0	48.0	42.5	24.2	34.7
CHN USA & USA CHN	7.1					
USA USR & USR USA	7.1					
CHN USR & USA USR		8.8				
CHN USR & USR CHN		8.8				
CHN USA & USR USA			6.5			
CHN USA				7.2		
USA CHN				7.2		
USA USR					9.7	
CHN USR & USR USA					12.7	
CHN USA & CHN USR						8.2
CHN USA & CHN USR						8.2
Total	57.6	47.6	54.5	56.9	46.6	51.1

Location Theory and the Social Sciences:
A Theory of Optimal Decisions for a Committee*

S.J. Thorson**

and

R.E. Wendell

Ohio State University

September 1973

Project Research Report No. 6

*A previous version was presented at the Location Theory Session, 43rd National Meeting of the Operations Research Society of America, May 1973.

**Assistant Professor of Political Science, the Ohio State University, and Assistant Professor of Operations Research and Political Economy, Carnegie-Mellon University, respectively.

1. Introduction to the Problem

Consider a situation where a benevolent chairman of a committee of m(finite) members must adopt a position on each of n(finite) issues. In general, each member of the committee will have different opinions on each of the n issues so that the chairman's ultimate position will be a compromise. In this paper we study the nature of such a compromise by considering two plausible objectives for the benevolent chairman. These two objectives are to minimize his perception* of total utility loss (i.e., total unhappiness) of the members and to minimize his perception* of the maximum utility loss of the members (i.e., the maximum unhappiness over all committee members). These objectives differ in that the former sums the loss of all the members for each possible position of the chairman while the latter determines the loss associated with the most unhappy member for each possible position of the chairman.

For each of these two objectives a hierarchical classification of formulations with various levels of abstractness is given. Since more specific results can be obtained with more specific assumptions about a decision situation, this classification allows for one to choose a particular formulation depending on the assumptions that he is willing to make. A correspondence to empirical results in the experimental psychology literature is provided and results from location theory are applied. As a result we are able, in particular, to give a better understanding of the phenomena in this decision problem and, in general, to give more insight

---

*We work with the chairman's perception of members' utility loss since we are interested in studying decisions made by him (her). Since all losses are perceptions of the chairman, it makes sense to add or to take the maximum of such utility losses without worrying about the well-known controversy of interpersonal comparison of utilities.

into the nature of decision compromises. In as much as the problem cuts across parts of political science, psychology, sociology, and economics, this paper further develops the relationship between operations research and the social sciences. The approach in this paper has its roots in the spatial analysis of a dictatorship in political science (in particular see [4]). Thus, one application of this theory is to the problem where a benevolent dictator of a country facing various issues should locate. Examples of two such issues might be combat troop strength in Vietnam and the amount of the federal budget allocated to the poverty program.

In more common management situations, however, we have a small committee with a benevolent chairman. One hypothetical example is when a chairman of an academic department must decide how many hours per week a faculty member should teach, how many he should perform administrative duties, and how many he should be allowed to consult. Certainly, faculty members would have different opinions on the performing of these tasks so that the chairman's ultimate decision will be a compromise.

To establish a framework to study decisions in such situations we make the following assumptions:

(1.1) There exists a one-to-one correspondence between positions on an issue and the set of real numbers;*

(1.2) Each member has a single most preferred position on each of the n(finite) issues.

---

*This assumption may only make sense for a subset of the set of real numbers. For example, negative numbers that correspond to negative hours may be meaningless. Such cases can be avoided by introducing constraints into the problem. See Section 4 for further discussion.

Such assumptions are common in spatial analysis (see [4] for a discussion of the implications). Under such assumptions we can define*:

(1.3) $P_i \equiv (P_i^1, P_i^2, \ldots, P_i^n)' \equiv$ the vector in R^n that characterizes the most preferred position of member i (as perceived by the chairman) for $i = 1,\ldots,m$ (finite) on the n issues;

$x \equiv (x^1, x^2, \ldots, x^n)' \equiv$ the vector in R^n corresponding to the chairman's position on the n issues;

$L_i(x) \equiv$ a function from R^n into R^1 that characterizes the chairman's perception of the utility loss to member i from his adopting a position at x.

Furthermore, we shall call R^n the <u>issue space</u>. Note that the framework just developed implies that P_i is a satiation point for member i in that P_i is the unique minimum of $L_i(x)$ over R^n.

We are now in a position to specify more specifically the chairman's problems. In particular, when the chairman desires to minimize total perceived utility loss we can represent his problem as

(T) $\min_x \sum_{i=1}^{m} L_i(x)$.

---

*The notation " ' " denotes the transpose of a vector. Furthermore, we use superscripts to denote components of a vector. The distinction between superscripts and exponents will be clear from the context.

Alternately, when he acts so as to minimize maximum utility loss his problem becomes

$$\text{(M)} \quad \underset{x}{\text{Min}} \left\{ \underset{i=1,\ldots,m}{\text{Max}} L_i(x) \right\} \quad .$$

In location theory, problem (T) corresponds to the Weber problem and problem (M) corresponds to the Spherical Covering Problem.

2. Hierarchical Classification of Abstraction

To make problems (T) and (M) more tractable we now develop more specific characterizations of the loss, $L_i(x)$, through the following definition

(2.1) A function $\rho(\cdot\,,\,\cdot)$ from* $R^n \otimes R^n$ into R^1 is said to be a weak metric** if:

(i) $\rho(y,z) \geq o$ for all $y,z \epsilon R^n$,

(ii) $\rho(y,z) = o$ iff $y = z$,

(iii) $\rho(y,z) \leq \rho(y,x)+\rho(x,z)$ for all $x,y,z \epsilon R^n$.

Furthermore, if $\rho(\cdot\,,\,\cdot)$ satisfies the condition

(iv) $\rho(y,z) = \rho(z,y)$ for all $y,z \epsilon R^n$ then $\rho(\cdot\,,\,\cdot)$ is said to be a metric.

A (weak) metric covers a very broad class of distance functions (see [30] for further discussion) and gives rise to a very general class of loss functions.

(2.2) $L_i(x) = C_i(\rho_i(x,P_i))$

where $C_i(\cdot)$ is a non-decreasing function from $[o,\infty)$ into R^1 and $\rho_i(\cdot\,,\,\cdot)$ is a (weak) metric corresponding to member i. Note that $\rho_i(x,P_i)$ is a measure of how far x is from P_i in the issue space and that $C_i(\cdot)$ gives the utility

---

*$R^n \otimes R^n$ means the Cartesian Product of R^n with R^n.

**Technically, since condition (ii) is assumed for the "only if" case as well as the "if" case, this is the definition of a definite weak metric.

loss as a function of this distance. Since both the perception of distance between two points in the issue space and the sensitivity to changes in distance may differ for each member, the metric $\rho_i(\cdot\,,\,\cdot)$ and the function $C_i(\cdot)$ are both indexed by i.

We now proceed to develop a hierarchical classification of abstraction for problems (T) and (M). For brevity we will explicitly develop the relationships only for problem (T). The relationships for problem (M) follow in an obvious manner by substituting $\left(\max_{i=1,\ldots,m}\right)$ for $\left(\sum_{i=1}^{m}\right)$.

The first such problem in the classification

$$\text{(T1)} \quad \min_x \sum_{i=1}^{m} C_i(\rho_i(x,P_i))$$

follows from substituting (2.2) into (T).

Unfortunately, not much can be said about problem (T1). Thus, we systematically proceed to consider special cases which have more specific structures.

In particular, consider the case in which $C_i(\cdot)$ is a linear function*

$$(2.3) \quad C_i(\xi) = W_i\xi$$

where W_i is a non-negative scalar. Because of its mathematical simplicity and its intuitive attractiveness, this form is especially significant. In particular, one might interpret W_i as a perceived rate of loss to member i (e.g., a full professor may have a higher rate than an assistant professor).

By substituting (2.3) into (T1) we get the new problem

$$\text{(T2)} \quad \min_x \sum_{i=1}^{m} W_i\rho_i(x,P_i).$$

---

*All of our results also apply to the case where $C_i(\xi) = W_i\xi+K_i$ since K_i is a constant.

As distinct from the linearity condition in (2.3), consider instead the situation where the chairman perceives each member as measuring distance via the same (weak) metric. This condition can be stated as:

(2.4) $\rho_i(\cdot\,,\cdot)$ is independent of i so that one (weak) metric $\rho(\cdot\,,\cdot)$ can be used to describe the distance measurement for all members.

According to this condition, the chairman sees a certain homogeneity in the committee members in that they may have different positions but they view the importance of each issue identically. Alternately, the chairman may never even consider the possibility that members perceive distance different from him. See [4] for a further discussion of this type of assumption.

In any event, when (2.4) holds problem (T1) becomes

$$\text{(T3)}\quad \operatorname*{Min}_{x} \sum_{i=1}^{m} C_i(\rho(x,P_i))$$

Of course, when (2.3) and (2.4) both hold, we get the problem

$$\text{(T4)}\quad \operatorname*{Min}_{x} \sum_{i=1}^{m} W_i\rho(x,P_i)$$

which is a special case of both (T2) and (T3). This relationship for problems (T1), (T2), and (T3) as well as other problems yet to be developed are illustrated in Figure 2.1.

Before developing other relationships, we first review the definition of a (weak) norm.

(2.5) A weak norm* is a function, denoted as $\|\cdot\|$, from R^n into R^1 with the following properties:

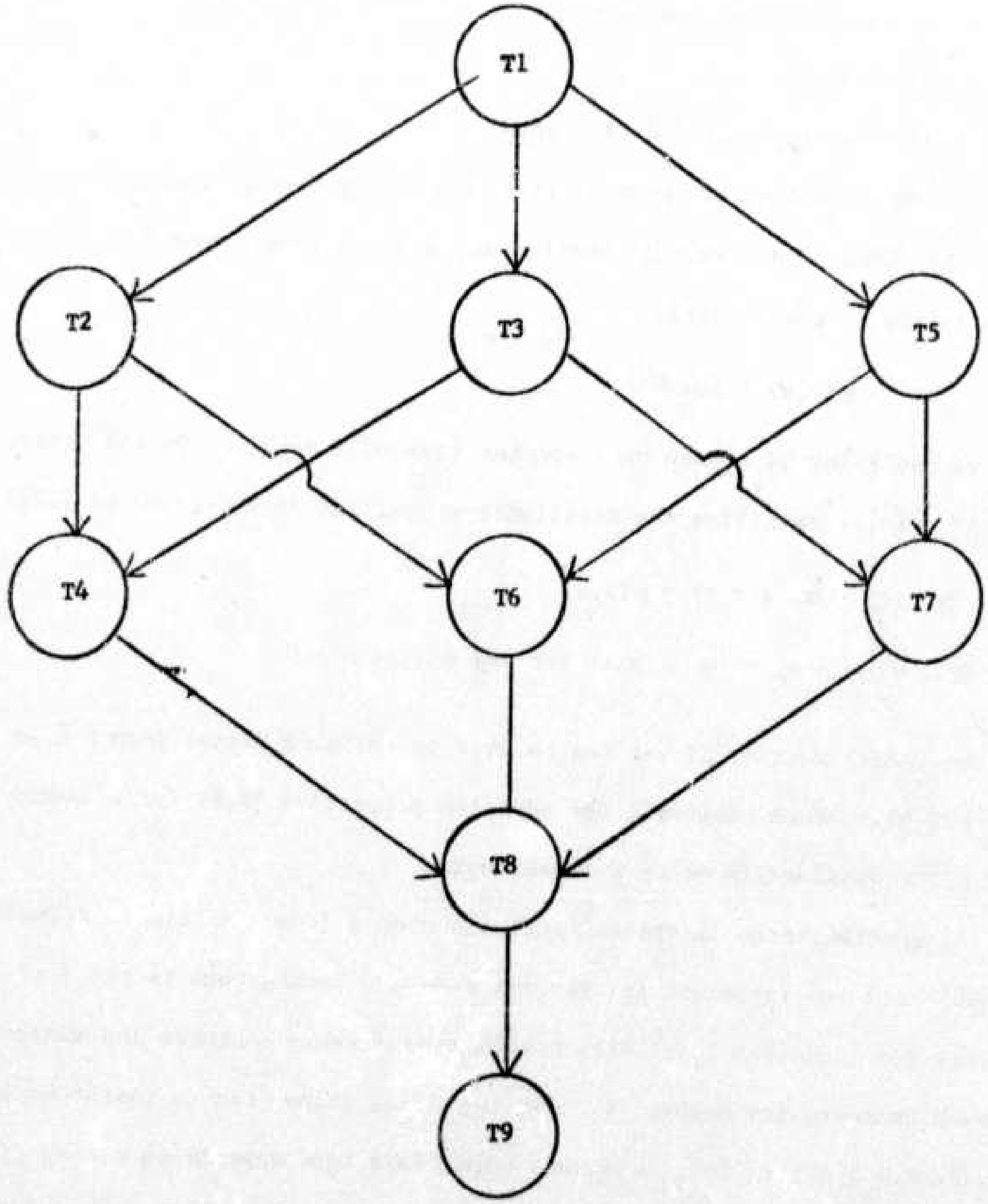
(i) $\|v\| \geq 0$ for all $v \in R^n$,

(ii) $\|v\| = 0$ iff $v = 0$,

(iii) $\|u+v\| \leq \|u\| + \|v\|$ for all $u,v \in R^n$,

(iv) $\|\alpha v\| = \alpha \|v\|$ for all $v \in R^n$ and any scalar $\alpha \geq 0$.

*Technically, as with the weak metric, this is a definite weak norm.



Interrelationship of the Formulations

Figure 2.1

If, in addition, we have

(v) $\|v\| = \|-v\|$,

then we say that $\|\cdot\|$ is a norm.

With the exception of property (iv), the properties of a metric are similar to those of a norm. In particular, given a (weak) norm $\|\cdot\|$ we can define a (weak) metric

$$\rho(u,v) \equiv \|u-v\| .$$

Thus, we can think of a norm as a special case of a metric. On the other hand, if $\rho(\cdot,\cdot)$ satisfies the additional properties (see page 50 of [20])

(2.6) (v) $\rho(y + x, z + x) = \rho(y,z)$

(vi) $\rho(\alpha y,\alpha z) = \alpha \rho(y,z)$ for any scalar $\alpha \geq 0$,

then the (weak) metric $\rho(\cdot,\cdot)$ can be used to define a (weak) norm $\|\cdot\|$ as $\|u\| \equiv \rho(u,o)$. Hence, assuming the addition properties (2.6) for a (weak) metric is equivalent to using a (weak) norm.

The special cases in spatial analysis when a (weak) metric is actually a (weak) norm are important for several reasons. Among them is the fact that any loss function $L_i(x)$ with convex indifference contours and where all such contours for member i have the "same shape" can be characterized as $C_i(\|x-P_i\|_i)$ where $\|\cdot\|_i$ is a weak norm whose type depends on member i (see [29] for a proof and further discussion). Further, if these indifference contours are symmetric about P_i then $\|\cdot\|_i$ is a norm. Thus, the class of all loss functions having these properties can be studied by using loss functions (2.2) where ...

$$(2.7) \quad \rho_i(x,P_i) = \|x-P_i\|_i \quad .$$

In particular, by substituting (2.7) into (T1), (T2), (T3), and (T4) we get the forumlations

$$(T5) \quad \min_x \sum_{i=1}^{m} C_i(\|x-P_i\|_i)$$

$$(T6) \quad \min_x \sum_{i=1}^{m} W_i\|x-P_i\|_i$$

$$(T7) \quad \min_x \sum_{i=1}^{m} C_i(\|x-P_i\|)$$

$$(T8) \quad \min_x \sum_{i=1}^{m} W_i\|x-P_i\|$$

respectively. Again, the relationship of these formulations to the other is given in Figure 2.1.

Finally, we consider a most special case where, in addition to all the other assumption, we also assume that the weights $W_i = 1$ for $i = 1,\ldots,m$. This assumption, which is paramount to assuming that the chairman perceives all members as having the same linear loss function, gives us the relatively simple formulation

$$(T9) \quad \min_x \sum_{i=1}^{m} \|x-P_i\|$$

Because of its simple nature it is especially helpful in giving insight into the more complex problems.

Recall that the motivation for the development of the preceding hierarchical classification of abstraction in problem formulations is based on the fact that different applications require different levels of information about the properties of the various functional forms. Since more

specific formulations yield more specific results, it is desirable to make the classification more detailed by considering important special cases of the previous formulations. We now do this by considering particular norms that have important interpretations in decision problems as well as important empirical justifications from experimental psychology.

The first such norm that we consider is the generalized Manhattan (i.e., city-block) norm $\|v\|$, defined as $\sum_{j=1}^{n} \delta^j |v^j|$, which is simply the weighted sum of the absolute values of the components v^j of v where the weights δ^j are positive. (When $\delta^j = 1$ for $j = 1,\ldots,n$ this becomes the usual Manhattan norm.) Thus, the distance between two points x and P_i measured via this norm is

$$(2.8) \quad \|x-P_i\|_i^{(1)} = \sum_{j=1}^{n} \delta_i^j |x^j - P_i^j|$$

where the subscript i allows for individual differences in these weights and where the superscript (1) in $\|x-P_i\|^{(1)}$ denotes that the norm is of the (generalized) Manhattan type.

In location theory this measure is important in cities having north-south and east-west streets. In an issue space this corresponds to a person measuring the distance by summing the weighted distances that two positions differ on each issue. In this case, the weight δ_i^j corresponds to the relative importance of issue j by member i. There is empirical evidence in the experimental psychology that indicates that such perceptions in distance are reasonable in many cases. See [29] and [21] for further discussion as well as introduction to the psychology literature.

By substituting (2.8) into problem (T5) we get the problem

$$\text{(T5.1)} \quad \min_{x} \sum_{i=1}^{m} C_i \left(\|x-P_i\|_i^{(1)}\right)$$

Similarly, by substituting (2.8) into (T6), (T7), (T8), and (T9) we obtain problems (T6.1), (T7.1), (T8.1), and (T9.1) in an obvious manner.

Another such norm is the generalized Tchebycheff norm $\|v\|$, defined as $\operatorname{Max}\{\delta^j|v^j|\}$, which is simply the maximum of n numbers where the jth number is the product of a positive weight δ^j and the absolute value of component v^j of v. (When $\delta^j = 1$ for $j = 1,\ldots,n$ this becomes the usual Tchebycheff norm.) Thus, the distance between two points x and P_i measured via this norm is

$$\text{(2.9)} \quad \|x-P_i\|_i^{(\infty)} = \max_{j=1,\ldots,n} \{\delta_i^j|x^j-P_i|\}$$

where the superscript (∞) on $\|x-P_i\|_i^{(\infty)}$ denotes that the norm is of this type.

Although this norm is not typical of facility location situations, it is very important in our decision analysis. In particular, with $\delta_i^j|x^j-P_i^j|$ representing the loss of member i on issue j relative to the other issues, this norm means that the loss of member i for some position x is the maximum of his losses on each issue. A person with this norm, for example, whose disagreement with Nixon's combat troop strength position for Vietnam is greater than his disagreement with Nixon on other issues would be insensitive to minor changes by Nixon on these other issues (i.e., his loss associated with Nixon's positions would not change). Again, there is some evidence in the psychology literature (again see [29] and [21]) to support such behavior.

Analogous to the Manhattan norm, we can substitute (2.9) into (T5) to get the problem (T5.∞)

$$\text{(T5.}\infty\text{)} \quad \underset{x}{\mathrm{Min}} \sum_{i=1}^{m} C_i \left(\|x-P_i\|_i^{(\infty)}\right) ,$$

and similarly we can substitute it into (T6), (T7), (T8), and (T9) to get (T6.∞), (T7.∞), (T8.∞), and (T9.∞).

The third norm that we consider is the generalized Euclidean $\|v\|$, defined as $[\sum_{j=1}^{n} \delta^j (v^j)^2]^{1/2}$, which is simply the square root of the sum of weighted squares. When the weights δ^j all equal one, this becomes the well known Euclidean norm that gives the straight line distance between two points. As such, it is the basis for much of our intuition as well as many of the basic results in location theory, in spatial theory as well as in experimental psychology (i.e., again see [29] and [21]).

The distance between two points x and P_i measured via this generalized Euclidean norm is

$$\text{(2.10)} \quad \|x-P_i\|_i^{(2)} = [\sum_{j=1}^{n} \delta_i^j (x^j-P_i^j)^2]^{1/2}$$

where the superscript (2) on $\|x-P_i\|_i^{(2)}$ denotes that the norm is of this type. Substituting (2.10) into (T5) we get the problem

$$\text{(T5.2)} \quad \underset{x}{\mathrm{Min}} \sum_{i=1}^{m} C_i \left(\|x-P_i\|^{(2)}\right)$$

with problems (T6.2), (T7.2), (T8.2), and (T9.2) obtained in an analogous way.

It should be noted that the generalization of the Euclidean norm just given results in elliptical indifference contours as opposed to circular ones.

By considering an orthogonal basis change these contours become rotated ellipses. See [4] and [19] for more details. Although, in general, this gives a norm that is a generalization of (2.10), note that under assumption (2.4) this just reduces to our case (2.10) (e.g., we can imagine making a basis change so as to use (2.10) with respect to the new basis).

Similarly, such rotations can be imagined for the other norms. Along these lines it is noteworthy that the Manhattan norm in R^2 is equivalent to the Tchebychoff norm under a 45 degree rotation. This equivalence in R^2, however, does not generalize to R^3 (see [33]).

In addition, it might be noted that the Manhattan, the Tchebycheff, and the Euclidean norms are just special cases of the l_p norm for $p = 1, \infty$, and 2 respectively. Other values of p between 1 and ∞ could also be considered.

Finally, the conditions on these specific norms can be weakened to yield weak norms. This important case still has many of the same properties that we develop in the next Section.

3. Properties of Optimal Location

In this Section we exploit some of the results from plant location problems to obtain various properties for the optimal location of the chairman. This is not just a direct application since the decision problem has formulations with both special structures and general structures not found in plant location problems. More specifically, plant location problems generally consider only the Manhattan and Euclidean norms. General norms and metrics as well as certain specific norms (e.g., Tchebycheff) are rarely considered.

One of the most precise (as well as useful) properties of an optimal position is the acual identification of its location. Although in general this specification is not possible, the following important theorem gives one case when it can be done.

Theorem

Consider problem (T4). If $\rho(\cdot,\cdot)$ is a metric and if $W_k \geq \sum_{\substack{i=1 \\ i \neq k}}^{m} W_i$, then $x^* = P_k$.

Proof*

$$\sum_{i=1}^{m} W_i \rho(x,P_i) \geq \sum_{\substack{i=1 \\ i \neq k}}^{m} W_i [\rho(x,P_k) + \rho(x,P_i)]$$

$$= \sum_{\substack{i=1 \\ i \neq k}}^{m} W_i [\rho(P_k,x) + \rho(x,P_i)] \geq \sum_{\substack{i=1 \\ i \neq k}}^{m} W_i \rho(P_k,P_i) = \sum_{i=1}^{m} W_i \rho(P_k,P_i)$$

where: the first inequality follows from $W_k \geq \sum_{\substack{i=1 \\ i \neq k}}^{m} W_i$; the first equality follows from property (iv) of (2.1); the second inequality follows from property (iii) of (2.1); and the second equality follows from property (ii) of (2.1).

Note that this theorem depends on neither the type of metric nor the geometric location of the points P_i. It is, therefore, a somewhat general sufficient condition for a point P_k to be an optimal position. Later, for specific metrics, we will obtain more specific conditions that are both necessary and sufficient.

---

*This new proof by R. E. Wendell and H. H. Wong is both shorter and more direct than that given in [36].

One interpretation of this theorem certainly makes the result plausible. If, for example, you interpret W_i as the power of the member(s) at position P_i, then P_k is an optimal position if the total power of members not at P_k is less than or equal to the power W_k. Although this may seem obvious, note that the result assumes that the chairman does not perceive differences in the types of metrics used by the different members (i.e., problem (T2)). If the chairman does perceive such differences, then the following theorem may be applicable.

Before giving the theorem, however, we first state a basic property of norms.

Lemma 1 (see page 132 of [20])

Let $\|\cdot\|_1$ and $\|\cdot\|_2$ be two given norms.

Then there exists

$L_2 > 0$ and $U_2 > 0$ such that for every $\xi \in R^n$ we have

$$L_2 \|\xi\|_2 \leq \|\xi\|_1 \leq U_2 \|\xi\|_2$$

For a given norm $\|\cdot\|_k$ we define

$$\bar{U}_i \equiv \text{Min } \{U_i : \|\xi\|_i \leq U_i \|\xi\|_k\} \text{ and}$$

$\bar{L}_i \equiv \text{Max } \{L_i : \|\xi\|_i \geq L_i \|\xi\|_k\}$. If, of course, all norms are of the same type, then $\bar{L}_i = \bar{U}_i = 1$. Although $\bar{U}_i \geq \bar{L}_i$ in general, it is possible that $\bar{U}_i \leq 1$.

Now (at least in theory) the chairman can determine the numbers $\bar{U}_i$ and then apply the following result.

Theorem 2 If in problem (T6) the function $\|\cdot\|_i$ are norms and if $W_k \geq \sum_{\substack{i=1\\i\neq k}}^{m} \tilde{U}_i W_i$, then $x^* = P_k$.

Proof

$$\sum_{i=1}^{m} W_i \|x-P_i\|_i \geq \sum_{\substack{i=1\\i\neq k}}^{m} \tilde{U}_i W_i \|x-P_k\|_k + \sum_{\substack{i=1\\i\neq k}}^{m} W_i \|x-P_i\|_i$$

$$\geq \sum_{\substack{i=1\\i\neq k}}^{m} W_i \|x-P_k\|_i + \sum_{\substack{i=1\\i\neq k}}^{m} W_i \|x-P_i\|_i$$

$$= \sum_{\substack{i=1\\i\neq k}}^{m} W_i \left[\|P_k-x\|_i + \|x-P_i\|_i\right]$$

$$\geq \sum_{\substack{i=1\\i\neq k}}^{m} W_i \|P_k-P_i\|_i = \sum_{i=1}^{m} W_i \|P_k-P_i\|_i$$

where, except for the second inequality which follows from Lemma 1, the steps are similar to the proof of Theorem 1.

Since problems (T4) and (T8) are equivalent in the case when the metrics are actually norms and since Theorem 2 applies to the generalization (T6) of problem (T8), Theorem 2 is a partial generalization of Theorem 1. Note that this generalization considers both the power weights W_i as well as the different types of norms used.

Unfortunately, the condition in Theorems 1 and 2 will usually not be satisfied. Thus, we must make different assumptions to obtain other results.

One such assumption, which has been explored in majority-rule processes by Downs [8], is a one-issue decision situation. For such a simple but important situation we have the following theorem.

Theorem 3

If $C_i(\cdot)$ are concave functions in problem (T5) and if $n=1$, then $x^* = P_k$ for some k.

This result is a special case of location on networks that has been considered in [31]. The interpretation of the concavity assumption is just diminishing marginal utility loss. In this important case, possible optimal positions are delimited to points in the set $\{P_1,\ldots,P_m\}$.

One of the obvious next steps is to consider a generalization of Theorem 3 to the case where P_i are collinear in $R^n (n\geq 1)$.

Unfortunately, as the following example shows, this generalization does not go through when different members have different types of metrics.

Example 1

Let $n = 2$, $m = 2$, $P_1 = \begin{pmatrix}1\\0\end{pmatrix}$, $P_2 = \begin{pmatrix}0\\1\end{pmatrix}$, and $\bar{x} = \begin{pmatrix}1\\1\end{pmatrix}$. Suppose both members use the generalized Euclidean norm (2.10) where

$\delta_1^1 = 4$, $\delta_1^2 = 1$, $\delta_2^1 = 1$, and $\delta_2^2 = 4$. Finally,

let $C_i(\|x-P_i\|_i^{(2)}) = \|x-P_i\|_i^{(2)}$ for $i = 1,2$.

Then, $C_1(\|\bar{x}-P_1\|_1^{(2)}) + C_2\ (\|\bar{x}-P_2\|_2^{(2)}) =$

$[4(0)^2 + 1(1)^2]^{1/2} + [1(1)^2 + 4(0)^2]^{1/2} = 2$

Now, any point $x \in$ c.h.$\{P_1,P_2\}$* has the form $\binom{\alpha}{1-\alpha}$ for $o \leq \alpha \leq 1$ so that $C_1(\|x-P_1\|_1^{(2)}) + C_2(\|x-P_2\|_2^{(2)}) = [4(\alpha-1)^2 + 1(1-\alpha)^2]^{1/2} + [1(\alpha)^2 + 4(-\alpha)^2]^{1/2}$ $= [5]^{1/2} > 2$. Thus, no $x \in$ c.h.$\{P_1,P_2\}$ is optimal and, in particular, neither P_1 nor P_2 is optimal. (An alternate example using the Tchebycheff and Manhattan norms is given in [30].)

In the case when all members use the same (weak) norm a generalization of Theorem 3 can be obtained. Its proof depends on the following lemma from [30].

Lemma 2

If for problem (T7) the points $\{P_1,...,P_m\}$ are collinear along come line L, then for each $x \notin L$ there exists $\bar{x} \in L$ such that

$$\sum_{i=1}^{m} C_i(\|\bar{x} - P_i\|) \leq \sum_{i=1}^{m} C_i(\|x-P_i\|).$$

Note that this lemma is interesting in its own right since it asserts that an optimal position will occur on line L. Indeed, we can even further reduce this to the subset c.h.$\{P_1,...,P_m\}$ of L. Furthermore, from the lemma and Theorem 3 we can state our generalization of Theorem 3.

Theorem 4

If the points $P_1,...,P_m$ are collinear, then for problem (T7) some P_k will be optimal.

Of course, collinearity is such a special case that it will rarely arise in practice. When it appears to arise, one might wonder if he really isn't simply in some "equivalent" one-issue case. On the other hand,

---

*c.h.{ } means the convex hull.

one might wonder about an apparent one-issue case really being "forced" collinearity in a multi-dimensional issue space.

Finally, we state a useful corollary to the preceding theorem.

Corollary

Suppose for problem (T8) that the points $\{P_1,\ldots,P_m\}$ are collinear along some line L. For this line L specify some direction of increase so that we can relate any two points P_i and P_k on L by the relationship $\geq$, $\leq$, $>$, $<$, and $=$. Then x^* on L is an optimal location iff

$$\sum_{\substack{i: \\ \{P_i < x^*\}}} W_i \leq \sum_{\substack{i: \\ \{P_i \geq x^*\}}} W_i$$

and

$$\sum_{\substack{i: \\ \{P_i \leq x^*\}}} W_i \geq \sum_{\substack{i: \\ \{P_i > x^*\}}} W_i$$

Furthermore (by Theorem 4), these conditions will be satisfied by some P_k.

Roughly speaking, this corollary has an obvious interpretation that power of all members to the "left" of x^* must be counterbalanced by the power of members to the "right." When all the weights are equal (as in (T9)), the point x^* is just the median of $\{P_1,\ldots,P_m\}$ along L.

We will now consider another generalization of Theorem 3 to a multi-issue space that does not make use of collinearity. In particular, we show

that under certain conditions an optimal position will occur among a finite set of "intersection points." We will not rigorously define an "intersection point" here (see [30]), but instead we illustrate the concept in Figure 3.1. Thus, in R^2 intersection points are given by the intersection of lines parallel to the axes through each point P_i. In R^3 we use planes instead of lines and in general we use hyperplanes. In R^1 the set of intersection points of $\{P_1,\ldots,P_m\}$ is simply the same set of points $\{P_1,\ldots,P_m\}$.

Theorem 5

Let $\{\delta_1,\ldots,\delta_k\}$ be the set of intersection points of the set $\{P_1,\ldots,P_m\}$. (Note that $k \leq m^n$.) If $C_i(\cdot)$ is an increasing function for $i = 1,\ldots,m$ in problem (T7) and if the norm in (T7) is in particular the generalized Manhattan norm (i.e., problem (T7.1)), then $x^* \in \{\delta_1,\ldots,\delta_k\}$.

See [28] for a proof of this result. Since (in a certain sense) all norms in R^1 can be considered equivalent, this result is a generalization of Theorem 3. At any rate it is generalization of the Manhattan norm case to R^n. Finally, a more specific version of the above theorem is now given.

Corollary

If in problem (T8) the particular norm used is the Manhattan norm, then a necessary and sufficient condition for x^* to be optimal is

$$\sum_{\substack{i: \\ \{x^{j*} > P_i^j\}}} W_i \leq \sum_{\substack{i: \\ \{x^{j*} \leq P_i^j\}}} W_i$$

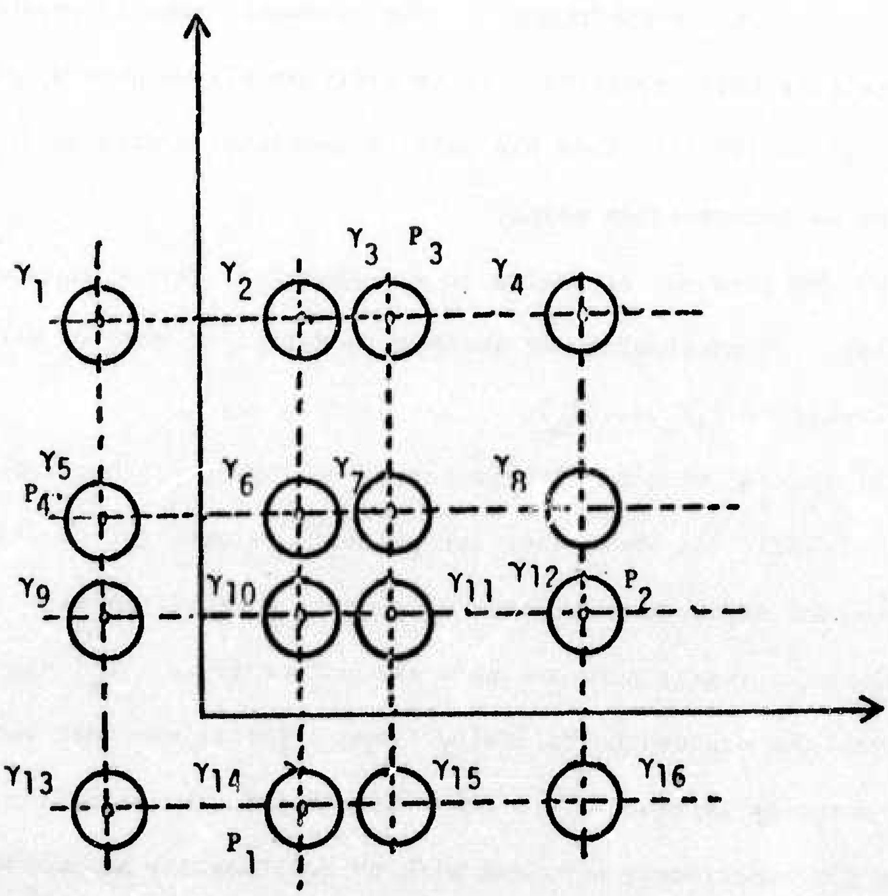

γ_1
γ_2
γ_3
P_3
γ_4
γ_5
P_4
γ_6
γ_7
γ_8
γ_9
γ_{10}
γ_{11}
γ_{12}
P_2
γ_{13}
γ_{14}
γ_{15}
γ_{16}
P_1

Figure 3.1

and

$$\sum_{\substack{i: \\ \{x^{j*} \geq P_i^j\}}} W_i \geq \sum_{\substack{i: \\ \{x^{j*} < P_i^j\}}} W_i$$

for $j = 1,\ldots,n$. Furthermore (by the Theorem), some intersection point will satisfy this condition. If in addition all weights W_i are equal (e.g., as in (T9.1)), then the multi-dimensional median of $\{P_1,\ldots,P_m\}$ will be an intersection point.

We now turn our attention to a somewhat different property of optimal solution. In particular, we attempt to determine when x^* will be in the convex hull of $\{P_1,\ldots,P_m\}$.

Of course, when $n = 1$ this convex hull property holds for (T5). For $n > 1$, Example 3.1 shows that the property is not true if different members use different metrics. Of course, when all persons use the same (weak) norm and when the points $\{P_1,\ldots,P_m\}$ are collinear in R^n, then the discussion following Lemma 1 points out that this convex hull property is true. This leads directly to the situation of all members using the same (weak) norm and with no collinearity assumption. A partial answer in this situation is given by the following theorem from [28].

<u>Theorem</u> 6

If for problem (T7) we have $n \leq 2$, then there exists an optimal position x^* in the convex hull of $\{P_1,\ldots,P_m\}$.

Counter to intuition (at least ours) this result, as the following example shows, does not go through for $n > 2$.

Example 2*

Consider problem (T9) with the Manhattan norm in R^3 and with $m = 3$. In particular, let

$$P_1 = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}, \quad P_2 = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}, \quad P_3 = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}.$$

Further, let $\bar{x} = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$ and note that

$$\|\bar{x} - P_1\|^{(1)} + \|\bar{x} - P_2\|^{(1)} + \|\bar{x} - P_3\|^{(1)} = 3$$

and $\bar{x} \notin$ c.h.$\{P_1, P_2, P_3\}$.

It is easy to show that when $x \in$ c. h. $\{P_1, P_2, P_3\}$

$$\|x - P_1\|^{(1)} + \|x - P_2\|^{(1)} + \|x - P_3\|^{(1)} = 4.$$

Thus, $x^* \notin$ c.h.$\{P_1, P_2, P_3\}$.

Although these results preclude the convex hull property in general for $n \geq 3$, there is at least one important case in which it is true. This is given by the following theorem from [17] or [30].

Theorem 7

For problem (T7) under the Euclidean norm, $x^* \in$ c.h.$\{P_1, \ldots, P_m\}$ for all n. ...

---

*The authors would like to acknowledge the help of Professor W. J. Davis (The Ohio State University) in preparing this example.

This result is probably the basis of most intuition which makes Example 3.2 so surprising. Note that Theorem 7 can be easily extended to the case of "generalized" Euclidean norms (i.e., those considered in [4], [18], and [19]) since the result is independent of rotation and scaling of the axes. On the other hand, Example 2.1 precludes a generalization to allowing different members to have different types of generalized Euclidean norms.

Still working with the Euclidean norm (for simplicity), we now turn our attention to the remarkable relationship of duality. In particular, consider problem (T8) under the Euclidean norm. We write this problem as

$$\Phi = \min_{x} \sum_{i=1}^{m} W_i \|x - P_i\|^{(2)}$$

and call it the <u>primal</u>. We now give its <u>dual</u> as the problem*

$$\Psi = \max_{y_1,\ldots,y_m} \sum_{i=1}^{m} \left\langle P_i , y_i \right\rangle$$

$$\text{s.t.}$$

$$\|y_i\|^{(2)} \leq W_i \quad \text{for } i = 1,\ldots,m$$

$$\sum_{i=1}^{m} y_i = 0.$$

The relationship between these two problems is given in the following theorem.

<u>Theorem</u> 8

The optimal values of the objective functions of the primal and dual problems are equal (i.e., $\Phi = \Psi$). Furthermore, the optimal solutions to

---

*The inner product $\left\langle P_i , y_i \right\rangle$ has its usual definition as $\sum_{j=1}^{n} P_i^j \, y_i^j$.

the above problems are related as follows:

$$y_i^* = \begin{cases} \dfrac{W_i(P_i - x^*)}{\|x^* - P_i\|^{(2)}} & \text{if } x^* \neq P_i \\ -\displaystyle\sum_{\substack{k=1 \\ k\neq i}}^{m} y_k^* & \text{if } x^* = P_i \end{cases}$$

See [17] for further discussion and a proof of the above duality theorem. For a generalization of the theorem to problem (T8) see [36]. Also, for a generalization to problem (T5) see [32]. To see how the primal problem can be solved via the dual, see [14].

In physics the primal problem can be interpreted as finding the point of minimum potential energy. One can think of this by considering the problem in R^2 and by imagining a smooth (frictionless) table top with holes at the points P_i. Then we get m strings, put the i^{th} string through the P_i, and attach a weight w_i to the end of the string hanging under the table. Finally, we tie all m strings together into one knot that is free to move on the top of the table. Since there is no friction, the knot will come to rest at the optimal location.

In physics there is a duality between potential energy and force. In particular, we can view the problem of minimizing potential energy as one of finding those set of forces $\{y_1^*,\ldots,y_m^*\}$ along the strings $1,\ldots,m$ respectively that sum to zero (e.g., are in equilibrium). The dual problem solves for this set of optimal forces.

The interpretation of these forces in political terms is especially interesting. In particular, a chairman located at x^* will "feel" a force on him y_i^* for $i = 1,\ldots,m$. Unless $x^* = P_i$, the magnitude of this force will be w_i. Furthermore, y_i^* gives an estimate of the sensitivity of Φ to perturbations of the point P_i. (See [17] and [32] for more details).

Since $\Phi = \Psi$ (i.e., no duality gap) and since the relationship between the optimal primal and dual variables are necessary and sufficient, one can derive the following theorem for optimal locations (see [32]).

Theorem 9

A solution x (not equal to any P_i) to the primal is optimal iff

$$\sum_{i=1}^{m} W_i \frac{(P_i - x)}{\|x-P_i\|^{(2)}} = 0$$

(Equivalently, letting e_j be the j^{th} unit vector in R^n, this condition can be written as

$$\sum_{i=1}^{m} W_i \cos \angle e_j, P_i - x = 0 \text{ for } j = 1,\ldots,n^*.$$

Note that the cosine terms in the above condition take account of the relative positions of the points P_i in R^n.)

A solution $x = P_i$ is optimal iff

$$\left\| \sum_{\substack{k=1\\k\neq i}}^{m} W_k \frac{(P_k - x)}{\|x-P_k\|^{(2)}} \right\|^{(2)} \leq W_i$$

$^*\cos \angle e_j, P_i - x$ is the cosine of the angle between the vectors e_j and $P_i - x$.

It is perhaps easiest to interpret the above theorem in terms of forces. In particular, if the chairman locates at some point $x = P_i$, then the force that citizen P_k (for $k \neq i$) is $\dfrac{W_k\,(P_k - x)}{\|x - P_k\|^{(2)}}$.

The vector sum of all such forces is

$$\sum_{\substack{k=1\\k\neq i}}^{m} W_k \frac{(P_k - x)}{\|x - P_k\|^{(2)}}$$

and this sum has the magnitude given by the left expression in Theorem 9. Since the magnitude of the force extended by member P_i is W_i, the theorem says that P_i is optimal iff the magnitude W_i is greater than or equal to the magnitude of the sum of forces of all other members. On the other hand, an optimal position x^* not equal to any P_i will occur iff the sum of all the forces at x^* is zero.

Again, the relative positions of the points P_i play an important role in the above result. Using the triangle inequality for norms we can easily derive the following sufficient condition which is true regardless of the relative position of the points P_i.

Corollary

If $\displaystyle\sum_{\substack{k=1\\k\neq i}}^{m} W_k \leq W_i$ then $x^* = P_i$

This, of course, is identical to Theorem 1 which we gave for a much more abstract problem (i.e., problem (T4)). Comparing Theorem 9 to Theorem 1 one can readily see how the additional structure (i.e., assuming the Euclidean norm) leads to a more powerful result. In particular, under the Euclidean norm, Theorem 9 gives a necessary and sufficient condition while Theorem 1 simply gives a sufficient condition (which is just a special case of Theorem 9).

Now, turning our attention from the Euclidean norm case, we point out the possible reformulation of certain problems into linear programs. In particular, problems of the form (T6) can be reformulated as linear programs when the types of norms are either the generalized Manhattan or the generalized Tchebycheff. We will not illustrate the absolute value "tricks" here, but instead we simply refer the reader to [35] (where the "tricks" are illustrated for the Manhattan norm). It is an easy exercise to apply them to the more general problems (see [34] for details).

Up to now we have only considerered the properties of problems of the type (T). For a summary of the main results for these problems see Figure 3.2 which associates theorems with the problem structures illustrated in Figure 2.1. Again, note that results true for geneal formulations apply to more specific ones while counter examples for specific formulations apply to more general ones.

As we have pointed out previously, the reader can easily imagine an analogous figure for problems of type (M) and one could develop results for (M) similiar to problem (T). In particular, obvious versions of Lemma 2, Theorem 6, Theorem 7, Example 1, and Example 2 apply to problem (M).

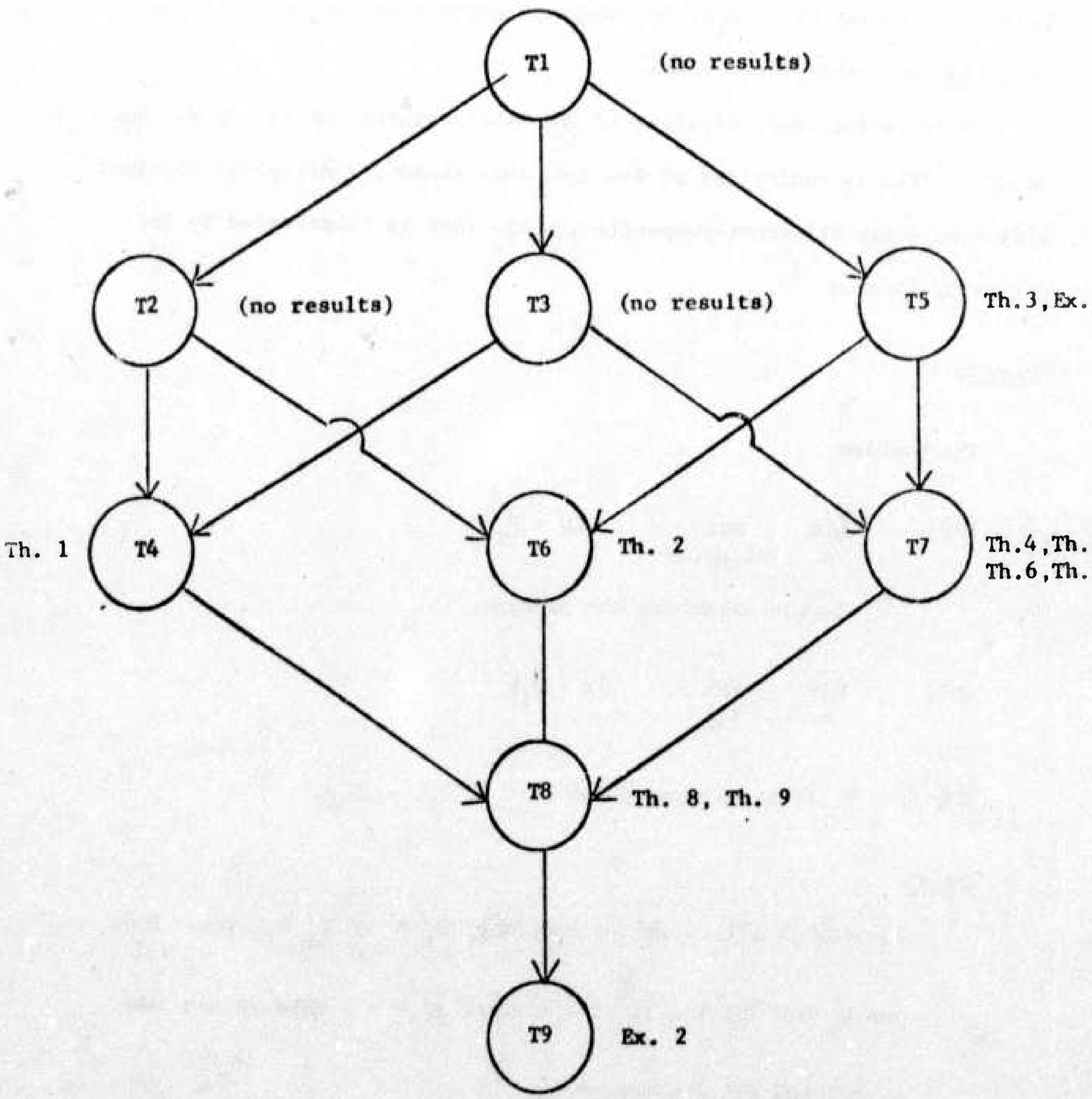

T1
(no results)
T2
(no results)
T3
(no results)
T5
Th.3, Ex.1
Th. 1
T4
T6
Th. 2
T7
Th.4, Th.5
Th.6, Th.7
T8
Th. 8, Th. 9
T9
Ex. 2

Figure 3.2

Also, both (T5) and (M5) are convex programs and have dual programs whose properties can be exploited (see [9] for a discussion of duality for (M5)). Finally, both can be reduced to linear programs under the generalized Manhattan and Tchebycheff norms.

On the other hand, versions of the other results for (T) do not apply to (M). This is indicative of the fact that these are different problems with some quite different properties. This fact is illustrated by the following theorem.

Theorem 10

The problem

$$\text{(M9)} \qquad \min_{x} \max_{i=1,\ldots,m} \|x - P_i\|$$

is equivalent to the problem

$$\text{(M9)} \qquad \min_{x} \max_{i \in I} \|x - P_i\|$$

$I \equiv \{i : P_i$ is an extreme point of c.h.$\{P_1,\ldots,P_m\}\}$.

Proof

For any $k \in \{1,\ldots,m\}$ we know that $P_k = \sum_{i \in I} \lambda_i P_i$ where $\sum_{i \in I} \lambda_i = 1$ and $\lambda_i \geq 0$ for $i \in I$. (Of course, if $k \in I$ then we can take $\lambda_k = 1$ and all other $\lambda_i = 0$.)

Thus, for any x

$$\|x - P_k\| = \|x - \sum_{i \in I} \lambda_i P_i\| \leq \sum_{i \in I} \lambda_i \|x - P_i\| \leq \max_{i \in I} \|x - P_i\|.$$

Hence, since k was arbitrary, we have $\max_{i=1,\dots,m} \|x - P_i\| \leq \max_{i\in I}\|x - P_i\|$.

But since I is a subset of $\{1,\dots,m\}$ equality must hold and the problems are equivalent.

This theorem shows that extreme points to the set $\{P_1,\dots,P_m\}$ are the only positions that matter in determining an optimal solution for (M9). This is not surprising in that members with extreme positions will be the critical ones in the process of minimizing maximum utility loss. This can be contracted to problem (T) where all points $\{P_1,\dots,P_m\}$ have an effect on the position of x^*.

Finally, to better understand the nature of this problem and its properties the reader should note that problem (M9) under the Euclidean, the Manhattan, and the Tchebycheff norms is equivalent to finding the center(s) of the smallest circle, diamond, and box respectively that covers the points $\{P_1,\dots,P_m\}$. (Thus, the name, Spherical Covering Problem). This problem has a long history and the reader might refer to [9] and [11] for a good introduction to it.

4. Conclusions and Comments

We have shown how a compromise decision can be viewed from a location theoretic perspective. Adopting such a perspective has important implications both to theoretical behavioral science and to location theory. With respect to the latter, we have reviewed and developed some results in abstract location theory and have shown how their interpretation is useful in understanding the various aspects of a compromise decision situation. The abstract approach adopted here is useful to the behavioral science since the less restrictive the assumptions made about the nature of the empirical world, the less must be known of the world in order to determine the applicability of the theory (for a related discussion of this point see [25]).

Of course, more specific assumptions do lead to more powerful statements about the nature of solutions (as illustrated by Theorem 1 and Theorem 9). The tradeoffs between abstractness and theoretical "power" are illustrated in the hierarchical classification of Figure 3.2.

Another product of this decision approach is that the mathematical concepts establish an unambiguous vocabulary for the underlying concepts as well as a style for analyzing phenomena. This becomes especially important in developing one's intuition in these areas since, as Examples 1 and 2 illustrate, intuition may be misleading. As a further example, consider the ambiguity of goals for a benevolent chairman. In particular, both (T) and (M) represent plausible goals in that (T) corresponds to maximizing total happiness of a committee while (M) can be interpreted as maximizing cohesion of a committee. Although these two objectives share some properties, we have seen how in general they are quite different (e.g., Theorem 10). For a further discussion on this point see [27].

A by-product of the paper is, of course, a review of many of the results in location theory. This review, however, is certainly not exhaustive. For example, multi-facility problems, network problems, and incorporation of constraints were hardly mentioned. It should be noted that this latter topic (i.e., constraints) does play an important role in the decision problem in characterizing feasible positions. For example, a teacher can only teach between 0 and 168 hours a week. Also, there may be budget constraints. Hence, although we have not explicitly considered them, constraints are an important consideration in the formulation and solution of decision problems.

The incorporation of constraints is, thus, one way in which the formulations in this paper may more precisely capture reality. Another way is to consider other formulations which may describe a particular situation.

One possible approach is to assume additive utility functions on each issue

for each member so that the chairman's problem is to

$$\underset{x}{\mathrm{Min}} \sum_{i=1}^{m} \sum_{j=1}^{n} U_{ij}(x) \quad .$$

This formulation is a special case of (T1) and has (T8.1) as a special case of it. Alternately, we might consider

$$\text{"Max"}_{i=1,\ldots,m} \quad \text{for} \quad \text{"}\sum_{i=1}^{m}\text{"} \qquad \text{and/or} \qquad \text{"Max"}_{j=1,\ldots,n} \quad \text{for} \quad \text{"}\sum_{j=1}^{n}\text{"}.$$

Some of the results in this paper can easily be extended to such formulations.

In addition, we point out that this paper has presented some new results in location theory. In particular, we have given a new proof to the Majority Theorem (Theorem 1) as well as a partial generalization of it (Theorem 2). Example 2 shows that the dominance results in [30] cannot in general be extended from R^2 to R^n for $n \geq 3$. Also we have contrasted problems (M) and (T) by showing the dependence of problem (M) on extreme points (i.e., Theorem 10).

Finally, in contrast to this paper, see [4], [19], [26], [29] and [33] for an analysis of the commitee decision analysis under majority rule.

REFERENCES

1. Arrow, K. Social Choice and Individual Values (2nd ed.). New Haven: Yale, 1963.

2. Attneave, F., "Dimensions of Similarity," American Journal of Psychology. 1950, 63, 516-566.

3. Black, D. The Theory of Committees and Elections. London: Cambridge, 1958.

4. Davis, O. A., Hinich, M. J., Ordeshook, P. C., "An Expository Development of a Mathematical Model of the Electoral Process," The American Political Science Review Vol. LXIV, No. 2, June, 1970, 426-448.

5. Dearing, P. M. and R. L. Francis, "A Network Flow Solution to a Multifacility Minimax Location Problem Involving Rectilinear Distances," (unpublished manuscript)

6. Debreu, G., Theory of Value. New Haven: Yale University, 1959.

7. Downs, A., "An Economic Theory of Political Action in a Democracy," Journal of Political Economy, 1957, 65, 135-150.

8. Downs, A. An Economic Theory of Democracy. New York: Harper, 1957.

9. Elzinga, D. J. and D. W. Hearn, "The Minimum Covering Sphere Problem," Management Science, September 1972, 19, 96-104.

10. Fischer, W. and H. C. Micko, "More About Metrics of Subjective Spaces and Attention Distributions," Journal of Mathematical Psychology, 1972, 9, 36-54.

11. Francis, R. L., "A Geometrical Solution Procedure for a Rectilinear Distrance Minimax Location Problem," unpublished Technical Note.

12. Goldberg, R. R. Methods of Real Analysis. Blaisdell, Waltham, 1964

13. Hotelling, H. "Stability in Competition," Economic Journal, 1929, 39 41-57.

14. Hurter, A. P. and A. Planchart, "Constrained Multifacility Location Problems with Mixed Norms: A Geometric Programming Approach," (unpublished manuscript).

15. Hyman, R. and A. Well, "Judgements of Similarity and Spatial Models," Perception and Psychophysics, 1967, 2, 233-248.

16. Kantorovich, L. V. and G. P. Akilov. Functional Analysis in Normed Spaces. Macmillan, New York, 1964.

17. Kuhn, H. W., "On a Pair of Dual Nonlinear Programs," in J. Abadie (ed.), Nonlinear Programming, John Wiley, New York, 1967, 37-54.

18. Ordeshook, P. C., "Extensions to a Model of the Electoral Process and Implications for the Theory of Responsible Parties," Midwest Journal of Political Science, Feb. 1970, Vol. XIV, No. 1, 43-70.

19. Riker, W. H. and P. C. Ordeshook, An Introduction to Positive Political Theory. Englewood Cliffs: Prentice Hall, 1973.

20. Rockafellar, R. T. Convex Analysis. Princeton, 1970.

21. Sherman, C. R., "Nonmetric Multidimensional Scaling: A Monte Carlo Study of the Basic Parameters," Psychometrika, 37, 323-355, 1972.

22. Shepard, R., "Attention and the Metric Structure of the Stimulus Space," Journal of Mathematical Psychology. 1964, 1, 54-87.

23. Smithies, A., "Optimal Location in Spatial Competition," Journal of Political Economy, 1941, 49, 423-429.

24. Stokes, D., "Spatial Models of Party Competition," American Political Science Review, 1963, 57.

25. Thorson, S. J. and J. Stever, "Classes of Models for Selected Axiomatic Theories of Choice," Journal of Mathematical Psychology (forthcoming).

26. Thorson, S. J. and R. E. Wendell, "Spatial Analysis of Electoral Behavior," (in preparation).

27. Thorson, S. J. and R. E. Wendell, "Justice and the Benevolent Dictator: A Spatial Approach," (in preparation).

28. Tullock, G., Toward a Mathematics of Politics. Ann Arbor, Michigan 1968.

29. Wendell, R. E., "Committee Decision Analysis under Majority Rule," (unpublished manuscript).

30. Wendell, R. E. and A. P. Hurter, "Location Theory, Dominance, and Convexity," Operations Research, 1973, 21, 314-319.

31. Wendell, R. E. and A. P. Hurter, "Optimal Location on a Network," Transportation Science, 1973, 7, 18-33.

32. Wendell, R. E. and E. L. Peterson, "Duality in Generalized Location Problems," Location Theory Session, Joint National Meeting of ORSA, TIMS, and AIIE, November 1972.

33. Wendell, R. E. and S. J. Thorson, "Some Generalizations of Social Decisions Under Majority Rule," Econometrica (forthcoming).

34. Wendell, R. E. and S. J. Thorson, "A Mathematical Study of Decisions in a Dictatorship," The George Washington University, Nonlinear Programming Symposium, March 1973.

35. Wesolowsky, G. O. and R. L. Love, "The Optimal Location of New Facilities Using Rectangular Distance," Operations Research, 1971, 19, 124-129.

36. Witzgall, C. Optimal Location of a Central Facility: Mathematical Models and Concepts. National Bureau of Standards Report 8388, Gaithersberg, Maryland, 1965.

Classes of Models for Selected
Axiomatic Theories of Choice[1]

Stuart J. Thorson
Project for Theoretical Politics
Department of Political Science
Ohio State University

John Stever
Center for Comparative Studies in
Technological Development & Social Change
University of Minnesota

1973
Project Research Report No. 7

The research described in this paper was in part
supported by ARPA Contract No. DAHC 15 73 C 0197.

Abstract

Adding a reversibility axiom to the other axioms of Luce's (1959) probabilistic ranking theory results in an impossibility theorem - that all alternatives in an alternative set are equally likely to be chosen (i.e. that preferences are random). This impossibility theorem is generally avoided by removing the reversibility axiom. Using simple algebraic methods such a modified theory is shown to contain a theorem similiar to the impossibility result. These results are discussed within the framework of mathematical model theory - model theory deals with the relations between sets of sentences (theories) and the structures which satisfy these sentences (models) - to illustrate the applicability of model theory as an analytic tool in theory development.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Project for Theoretical Politics The Ohio State University 053 Administration Building	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

"Classes of Models for Selected Axiomatic Thoeries of Choice"

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Research Report # 7

5. AUTHOR(S) (First name, middle initial, last name)

Stuart J. Thorson
John Stever

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
July 30, 1973	27	8

8a. CONTRACT OR GRANT NO DAHC15 73 C 0197 b. PROJECT NO A.O. 2345-3D20 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) # 7 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited and production in whole or in part is permitted for any purpose of the United States Government.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Advanced Research Projects Agency Washington, D.C.

13. ABSTRACT

Adding a reversibility axiom to the other axioms of Luce's (1959) probabilistic ranking theory results in an impossibility theorem - that all alternatives in an alternative set are equally likely to be chosen (i.e., that preferences are random). This impossibility theorem is generally avoided by removing the reversibility axiom. Using simple algebraic methods such a modified theory is shown to contain a theorem similar to the impossibility result. These results are discussed within the framework of methematical model theory - model theory deals with the relations between sets of sentences (theories) and the structures which satisfy these sentences (models) - to illustrate the applicability of model theory as an analytic tool in theory development.

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Choice Theory						
Model Theory						
Probabilistic ranking theory						

UNCLASSIFIED
Security Classification

Considerable work by mathematical psychologists has been devoted to developing axiomatic theories of choices. In this paper, a particular set of probabilistic ranking theories (PRT) (Luce & Suppes, 1965) will be examined from a model-theoretic perspective. Probabilistic theories of choice are those which assume that an individual's choice responses are governed by probability mechanisms and ranking theories are those which attempt to explain (describe) relations between results of experiments in which individuals are asked to select one item from among a number of alternatives and experiments in which he is asked to rank order the alternatives.

Some of the most important theoretical work in the area of PRT may be found in Luce (1959). Unfortunately, nearly all attempts to develop PRT quickly lead to the apparently anomolous result to be shown below (Block & Marschak, 1960, p. 111; Luce, 1959, p. 69; Luce & Suppes, 1965, pp. 356-358).

First, however, the axioms of the theory must be carefully specified. In doing this, it is important (the reasons for this will become clear later) to distinguish between the "calculus axioms" and the "proper axioms. Calculus axioms are those containing no "extra-logical constants" (Braithwaite, 1959, p. 429) and may be thought of as providing the basic logic for manipulating the sentences in the theory. Proper axioms, on the other hand, are those containing non-vacuously extra logical constants and correspond to the "substantive" axioms for the theory.

The Axioms

The distinction between calculus and proper axioms will be made more clear by a specific consideration of the axiom sets used by Luce (1959). The calculus axioms for Luce's PRT

are those of the probability calculus and are set out as below:

ca(1) For $S \subset T$, $0 \leq P_T(S) \leq 1$

ca(2) $P_T(T) = 1$

ca(3) If $R, S \subset T$ and $R \cap S = \emptyset$, then $P_T(R \cup S) = P_T(R) + P_T(S)$.

In axiom ca(1), T is a finite subset of the universal set U, and it is asserted that for any subset S of T, the probability that some element x (of T) is in S (designated by $P_T(S)$) is greater than or equal to zero and less than or equal to one. Axiom ca(2) tells us the probability that some element x (of T) is in T equals one. Axiom ca(3) says that if R and S are two subsets of T such that the intersection of R and S is the empty set ($\emptyset$), the probability that some element x (of T) is in R union S equals the sum of the probabilities that x is in R or S.

The next thing to be done is to specify the proper axioms. Let us restrict ourselves to situations in which an individual is faced with three alternatives, and let $A = \{a, b, c\}$ denote an arbitrary set with three elements. Then $P_A(x)$ will be the probability that an individual will choose x as his most preferred alternative from the set A (that is, the variable x may take on the value a, b, or c). A might be the set of dishes on a menu with "a" representing roast beef, "b" steak, and "c" hamburger. $P_A(a)$ would then be the probability of preferring roast beef out of the alternatives in A.

Further, let $p(x, y)$ denote the probability that an individual prefers alternative x to alternative y in the reduced set $\{x, y\}$. Finally, $\overline{p}(x, y, z)$ will be the probability of ranking the three alternatives from most preferred to least preferred in the order x, y, z. The notation $p(x, y)$ and $\overline{p}(x, y, z)$ is an abbreviation of the set notation introduced above. For example, $p(x, y)$ replaces $P_{\{x, y\}}(x)$, and statements like $P_{\{x, y\}}(x) + P_{\{x, y\}}(y) = P_{\{x, y\}}(\{x, y\}) = 1$ are rewritten

as $p(x, y) + p(y, x) = 1$. It will be assumed throughout this paper that none of the functions P_A, p, $\overline{p}$ takes the value zero for any argument.

With this notation several proper axioms relating how alternatives are ranked can be written. The first such axiom will be the <u>decomposition</u> axiom:

pa(1) (Decomposition): $\overline{p}(x, y, z) = P_A(x)p(y, z)$

The decomposition axiom simply states that the probability of preferring x to y and y to z may be decomposed into the product of the probability of choosing x as the most preferred alternative in A and the probability of preferring y to z.

The second assumption is the consistency axiom:

pa(2) (Consistency): (i) $P_A(x) = \overline{p}(x, y, z) + \overline{p}(x, z, y)$

(ii) $p(x, y) = \overline{p}(x, y, z) + \overline{p}(x, z, y) + \overline{p}(z, x, y)$

The intended interpretation of this axiom should be fairly self evident. It simply asserts that there is consistency between choice rankings and that adding irrelevant alternatives will not change the ranking. An important concern then might be in alternative ways of calculating $p(x, y)$. That is, what is the probability of say, preferring steak to roast beef when hamburger is not available? Proper axioms (1) and (2) together with the calculus axioms can be used to prove:

Theorem 1: $p(x, y) = \dfrac{P_A(x)}{P_A(x) + P_A(y)}$

Proof:

(1) $p(x, y) = P_A(x)p(y, z) + P_A(x)p(z, y) + P_A(z)p(x, y)$

by pa(2)(ii) and pa(1)

(2) $p(x, y)\ (1 - P_A(z)) = P_A(x)(p(y, z) + p(z, y)) = P_A(x)$

since $p(y, z) + p(z, y) = 1$

(3) $p(x, y) = \frac{P_A(x)}{(1 - P_A(z))}$ $\qquad$ $1 - P_A(z)$ is assumed to be $\neq 0$

(4) $1 - P_A(z) = P_A(x) + P_A(y)$ $\qquad$ by ca(2) and ca(3)

(5) $p(x, y) = \frac{P_A(x)}{P_A(x) + P_A(y)}$ $\qquad$ by substitution of (4) into (3).

Theorem 1, in a more general form, is known as Luce's choice axiom. It can easily be shown that Theorem 1 together with proper axiom 1 or proper axiom 2 implies the other proper axiom. This can be shown to be true where the cardinality of the alternative set A is any finite n and <u>not</u> only for n equal to three. Equally important, there is empirical evidence suggesting that Theorem 1 provides highly accurate predictions of reduced set choice probabilities for certain types of alternative sets.

Now, let $P_A*(x)$ be the probability of choosing x as the <u>least</u> preferred alternative in A. Similarly, let $p*(x, y) = P^*_{\{x, y\}}(x)$ and let $\bar{p}*(x, y, z)$ be the probability of having the rank order x, y, z when asked to rank from least preferred to most preferred. The last proper axiom, the reversibility axiom, can now be stated:

pa(3) (Reversibility): (i) $\bar{p}*(x, y, z) = \bar{p}(z, y, x)$

(ii) $p*(x, y) = p(y, x)$

(iii) pa(1) and pa(2) hold for P_A^*, p^*, $\bar{p}^*$

The reversibility axiom simply states that the probability of getting a certain ranking when going from most preferred to least preferred is the same as getting the reverse of that ranking when the criterion is going from least to most preferred.

Surprisingly, it is possible to prove that if decomposition, consistency, and reversibility hold, all alternatives are preferred with equal probability, that is, that preferences are random. In other words:

Theorem 2: $P_A(a) = P_A(b) = P_A(c) = P_A{}^*(a) = P_A{}^*(b) = P_A{}^*(c) = 1/3$.

Proof: It will be sufficient to show $P_A(x) = P_A(y)$, since axiom pa(3) implies the same result for $P_A{}^*$.

(1) $\bar{p}(x, y, z) = P_A(x)p(y, z)$ by pa(1)

(2) $\bar{p}^*(z, y, x) = P_A{}^*(z)p^*(y, x) = P_A{}^*(z)p(x, y)$ by pa(3)(iii) and (ii)

(3) $P_A(x)p(y, z) = P_A{}^*(z)p(x, y)$ by pa(3)(i) applied to steps (1) and (2)

(4) $P_A(x) = \dfrac{P_A{}^*(z)p(x, y)}{p(y, z)}$ by rewriting (3)

(5) $P_A(y) = \dfrac{P_A{}^*(z)p(y, x)}{p(x, z)}$ by interchanging x and y in (4)

(6) $p(x, y) = \dfrac{P_A(x)}{P_A(x) + P_A(y)}$ Theorem 1

(7) $p(x, y) = \dfrac{\dfrac{P_A{}^*(z)p(x, y)}{p(y, z)}}{\dfrac{P_A{}^*(z)p(x, y)}{p(y, z)} + \dfrac{P_A{}^*(z)p(y, x)}{p(x, z)}}$ by substituting (4) and (5) into (6)

(8) $p(x, z) = p(y, z)$ by simplification of (7)

(9) $p(x, y) = P(z, y)$
$p(y, x) = p(z, x)$ by interchanging the positions of x, y, z in (8)

(10) $p(z, x) = p(z, y)$ since $p(z, x) = 1 - p(x, z) = 1 - p(y, z) = p(z, y)$

(11) $p(x, y) = p(y, x) = 1/2$ by (9) and (10)

(12) $P_A(x) = P_A(y)$ substituting 1/2 for $p(x, y)$ in (6) .∎

(For a proof of Theorem 2 for the n-alternative case, see Luce & Suppes, 1965, pp. 356-358.)

These results seem contrary to experience. Unfortunately, the culprit is not obvious. Proper axioms (1) and (2) are the most likely suspects. However, together they imply Luce's choice axiom (Theorem 1) which has considerable empirical support. Moreover, Luce's choice axiom together with either proper axiom 1 or 2 implies the other. Thus if it is wished to retain Theorem 1 as a theorem, both proper axiom (1) and (2) must be retained. If, on the other hand, Theorem 1 is made an axiom, then both pa(1) and (2) must be thrown out. Axiom (3) (reversibility) seems to be some psychologist's favorite candidate for elimination. Their argument is that it makes no operational sense to ask a person to pick his "least preferred" alternative from some set of (homogeneous) alternatives. At least at first glance this claim appears very unconvincing (though the reader who sees potential merit in it is referred to Luce & Suppes, 1965, p. 358, where the position is spelled out). One need only introspect for a moment on the alternative set consisting of a thousand dollar bill, a hundred dollar bill, and a one dollar bill. Few people would find it difficult to pick out their least preferred alternative.

Theorem 2 is not, it would seem, a trivial result. It was obtained by making three apparently innocuous assumptions about how individuals related choice probabilities over a three alternative set. Yet these proper axioms together imply that unless $P_A(a) = P_A(b) = P_A(c)$, any individual who ranks the alternative elements of a three element set in the same fashion regardless of whether he ranks them from most preferred to least preferred or from least preferred to most preferred is exhibiting behavior which is inconsistent with that described by proper axioms (1) and (2).

What then is the theorist to do in the face of such an anomaly? One option is, of course, to ignore proper axiom (3) and simply develop

the theory using proper axioms (1) and (2). A second option is to investigate the mathematical structure underlying the axioms in question to see whether results which appear disturbing result directly from equally disturbing (but more subtle) properties of the class of models satisfying these axioms (and therefore theorems as well). Indeed, this appears to be the approach suggested by Luce and Suppes (1965) when they wrote:

"They (criticisms of probabilistic choice theories) suggest that we cannot hope to be completely successful in dealing with preferences until we include some mathematical structure over the set of outcomes that, for example, permits us to characterize those outcomes that are simply substituable for one another and those that are special cases of others. Such functional and logical relations among the outcomes seem to have a sharp control over the preference probabilities, and they cannot long be ignored [p. 337]." While it is not completely clear what is meant by the above passage, it does seem they are suggesting a closer investigation of the mathematical (logical) structures underlying various theories of choice. This paper represents an attempt to explore this suggestion for probabilistic ranking theories which contain proper axioms (1) and (2).

Model Theory

In most of the behavioral science literature, no clear distinction is drawn and maintained between models and theories. Indeed, perhaps the most common practice is to use "model" and "theory" interchangeably as synonyms as in Tversky (1972): "Since the present theory describes choice as an elimination process governed by successive selection of aspects, it is called the elimination-by-aspects (EBA) model [p. 285]". It would seem that, from Professor Tversky's perspective, it could as well have been called the EBA theory.

There certainly is nothing wrong with having synonyms for such frequently used words as "theory." However, when "theory" is used in its technical sense, there is a clear distinction which can be made between "models" and "theories," and this distinction has useful consequences for the topic at hand. A theory, in its technical sense, is a set of sentences which is closed under deduction; that is, the set contains any sentence that is logically implied by any other sentences in the set. This concept requires some preassigned logical framework (e.g., first-order predicate calculus) (Quine, 1968, p. 281). Whenever an axiom system is proposed (as in Tversky, 1972), this usage of "theory" is implied. On the other hand, a nontechnical theory is simply a set of sentences asserted to be true. For example, the entire body of knowledge on some subject may be referred to as the theory of that subject, as in the phrase "choice theory."

A corresponding technical notion of a model for a set of sentences (theory) is a mathematical structure which satisfies those sentences. Thus a model is a set-theoretic structure while a theory is a collection of sentences in some language. More specifically, a set-theoretic structure M is a set of elements (objects), $A = \{a_1, a_2, \ldots\}$, together with a set of relations of order i, $P_1^{i_1}$, $P_2^{i_2}$, ..., and may be expressed

$$M = \langle A; P_1^{i_1}, P_2^{i_2}, \ldots, P_n^{i_n}, \ldots \rangle .$$

A formal language L in which properties of M can be expressed will consist of formulas generated by a specified set of rules, say the predicate calculus, from an alphabet consisting of relation symbols (R_1, R_2,..), variable symbols (x_1, x_2,...), connectives ($\neg, \vee, \wedge, \ldots$), and quantifiers ($\forall, \exists$). Since functions and constants are special kinds of relations, function symbols (f_1, f_2,...) and constant symbols (c_1, c_2,...) will also be used in L. The language L will be assumed to be first order, that is,

its variables range over the elements of A (as opposed to ranging over the subsets of A, or sets of subsets, etc.). Sentences in L are formulas containing no free variables.

Let T be a set of axioms in a language L. If φ is a mapping of constant symbols occurring in T into the set of objects A, and also a mapping of relation symbols occurring in T into the set of relations in M, then M provides an interpretation of T under φ. If this interpretation results in the sentences in T being true, then M is said to satisfy T and M is a model of the axiom set T. A model for a set of axioms then, is a set-theoretic mathematical structure which interprets the axioms in such a way that the axioms are true.

The distinction just made between objects and symbols denoting objects (constants) and between relations and relation symbols should be emphasized. The reason for this distinction is that each mapping onto the objects and relations in a structure M provides an interpretation of the symbols in T. This is important since (as will be shown) a given axiom set can have more than one interesting interpretation, and only some of them will be models of the set.

One of the most obvious problems with the above definition of model is what is meant by a sentence being "true." Rather than provide an extended discussion of truth, the reader is referred to Tarski (1944). The important question here is not how do we know whether a particular sentence is in fact true but rather what is meant by asserting a sentence to be true. This latter semantic question is treated in considerable detail by Tarski for important classes of formal languages (including those to be dealt with in this paper).

In order to make this definition of model more clear, consider a very simple theory T' which contains only two proper axioms:

A1: $(\forall x_1)\ \neg(x_1 R x_1)$

A2: $(\forall x_1)(\forall x_2)(\forall x_3)[(x_1 R x_2 \wedge x_2 R x_3) \supset x_1 R x_3]$.

Consider further the following two mathematical structures:

M^*: $\langle A; P^2 \rangle$ where A is a finite set of alternatives and P^2 is the binary relation "is preferred to"

and

M^{**}: $\langle L; F^2 \rangle$ where L is the set of living males and F^2 is the binary relation "is the father of".

If the symbol R is mapped onto P^2, and the variables are assumed to range over A, then A1 would read as "for all alternatives in the set A, it is never the case that an alternative in A is preferred to itself." Axiom A2 would read: "For any triple of alternatives in the set A, if the first alternative is preferred to the second, and the second is preferred to the third, then the first alternative is preferred to the third." To claim M^* to be a model of T' is to assert the truth of these two sentences (A1 and A2). Further, Tarski (1944) shows that asserting a sentence to be true is equivalent to saying it is satisfied by all its objects. Again, there exists no algorithm for determining whether a particular sentence is in fact satisfied by all its objects. However, to assert that T' is modeled by M^* is to say that each sentence in T' is satisfied by all its objects.

Let us now examine the relation between the structure M^{**} and the sentences in T'. Do we want to assert that M^{**} is a model of T'? In this case the φ function maps the relation symbol R onto the relation F^2. Interpreting A1 with M^{**} results in the sentence:

> "For all males in the set of all living males, it is never the case that a male is the father of himself."

To assert that M^{**} is a model for T' is to assert this to be a true sentence. And, indeed, the sentence is empirically true. However, we must be careful not to move hastily from this observation to asserting that M^{**} is a model for T'. The definition of a model requires that all the axioms be true when interpreted by a model. Consider A2. Under M^{**} we have the following sentence:

> "For any three males in L, if $male_1$ is the father of $male_2$, and $male_2$ is the father of $male_3$, then $male_1$ is the father of $male_3$."

Again, to assert M^{**} is a model for T' is to assert the truth of this sentence. Yet this sentence is empirically untrue. Indeed, an ordinary language translation of this sentence would result in the assertion that a grandfather is the father of his grandson. The reason "is preferred to" seems a satisfactory interpretation of R and "is the father of" does not is that "is preferred to" is generally thought to be a transitive relation (as asserted by A2) and "is the father of" is not transitive. Thus the structure M^{**} is not a model for T'.

Another transitive relation is "is greater than." If the letter "I" denotes the set of integers, and ">" denotes "is greater than," then the structure $\langle I, >\rangle$ is a model for T'. A third transitive relation "is greater than or equal to" may be denoted by "$\geq$". Consider whether the structure $\langle I, \geq\rangle$ is a model of T'. Clearly axiom A2 is true with this interpretation; however, A1 reads as follows:

> "For any integer, it is never the case that the integer is greater than or equal to itself."

Most of us would assert this sentence to be false and not allow $\langle I, \geq\rangle$ as a model for T'.

Hopefully, these overly simplistic examples provide a general sense of how the terms "model" and "theory" are being used in this paper. Moreover, it should be clear from the above discussion that it is possible to develop a theory of models. In Robinson's (1963) words: "Model theory deals with the relations between the properties of sentences or sets of sentences specified in a formal language on one hand, and of the mathematical structures or sets of structures which satisfy these sentences, on the other hand [p. 1]".

Note the similarity between Robinson's definition of model theory and Luce and Suppes' quote in the previous section. In the next section a result analogous to Theorem 2 (proved using proper axioms (1) - (3)) will be shown to exist for the more commonly encountered proper axioms (1) and (2), and some of the model theoretic concepts introduced here will be used to analyze these two axiom sets.

Algebraic Results

This section begins with some algebraic manipulations on the equations in proper axioms (1) and (2). The results, theorems 3 and 4, together with theorems 1 and 2, will then be discussed in model-theoretic terms.

In the three alternative case there are six possible rankings of those alternatives. For notational convenience the corresponding probability values will be denoted by the set of symbols $\mathcal{T} = \{a_1, a_2, b_1, b_2, c_1, c_2\}$ as follows:

$\bar{p}(x, y, z) = a_1$ $\quad$ $\bar{p}(y, x, z) = b_2$

$\bar{p}(x, z, y) = a_2$ $\quad$ $\bar{p}(z, y, x) = c_1$

$\bar{p}(y, z, x) = b_1$ $\quad$ $\bar{p}(z, x, y) = c_2$

The following derivation in terms of the value $a_1 = \bar{p}(x, y, z)$ may be applied to each of the elements in $\mathcal{T}$. In the decomposition formula for $\bar{p}(x, y, z)$,

$$\bar{p}(x, y, z) = P_A(x) \cdot p(y, z). \tag{1}$$

(1) may be expanded by making substitutions on the right according to the formulas in axiom pa(2), yielding

$$\bar{p}(x, y, z) = (\bar{p}(x, y, z) + \bar{p}(x, z, y))(\bar{p}(x, y, z) + \bar{p}(y, z, x) + \bar{p}(y, x, z)). \tag{2}$$

Substituting the notation from above yields the equation

$$a_1 = (a_1 + a_2)(a_1 + b_1 + b_2). \tag{3}$$

Expanding the right side of (3)

$$a_1 = a_1^2 + a_1a_2 + a_1b_1 + a_1b_2 + a_2b_1 + a_2b_2, \tag{4}$$

and collecting terms

$$0 = a_1^2 + (a_2 + b_1 + b_2 - 1)a_1 + a_2(b_1 + b_2), \tag{5}$$

yields a quadratic expression in a_1. Applying the quadratic formula to solve for a_1 results in

$$a_1 = \frac{1 - (a_2 + b_1 + b_2) \pm \sqrt{(1 - (a_2 + b_1 + b_2))^2 - 4a_2(b_1 + b_2)}}{2}. \tag{6}$$

And letting $g(y_1, y_2, y_3)$ denote the function represented in (6),

$$g(y_1, y_2, y_3) = \frac{1 - (y_1 + y_2 + y_3) \pm \sqrt{(1 - (y_1 + y_2 + y_3))^2 - 4y_1(y_2 + y_3)}}{2}, \tag{7}$$

the results of applying the above procedure (1 - 6) to each of the six rankings are abbrev[illegible] as follows:

$$\begin{array}{ll} a_1 = g(a_2, b_1, b_2) & b_2 = g(b_1, a_1, a_2) \\ a_2 = g(a_1, c_1, c_2) & c_1 = g(c_2, b_1, b_2) \\ b_1 = g(b_2, c_1, c_2) & c_2 = g(c_1, a_1, a_2). \end{array} \tag{8}$$

Making the natural assumption that all the probability functions are real-valued, the quantity under the radical in (7) must be nonnegative, thus yielding six inequalities of the form

$$(1 - (y_1 + y_2 + y_3))^2 - 4y_1(y_2 + y_3) \geq 0. \tag{9}$$

In the next section, the consequences of varying this assumption are considered.

Suppose now that the values in $\mathcal{T}$ are not all equal. What are the implications of the equations and inequalities derived above upon the range of values that elements of $\mathcal{T}$ may assume? Theorems 3 and 4 and Inequality (17) show that even after removing axiom pa(3), the elements of $\mathcal{T}$ can take on relatively few values.

In order to further simplify the algebraic calculations, let the variable symbol α be defined in the following equation:

$$y_1 + y_2 + y_3 = 1/2 + \alpha . \tag{10}$$

Substituting (10) into (9) gives

$$(1 - (1/2 + \alpha))^2 - 4y_1(y_2 + y_3) \geq 0, \tag{11}$$

and rewriting (10) as $(y_2 + y_3) = 1/2 + \alpha - y_1$ gives

$$(1 - (1/2 + \alpha))^2 - 4y_1(1/2 + \alpha - y_1) \geq 0 \text{ ,and} \tag{12}$$

$$y_1^2 - (1/2 + \alpha)y_1 + \frac{(1/2 - \alpha)^2}{4} \geq 0 . \tag{13}$$

Applying the quadratic formula again, this time to find the zeros in (13), the expression on the left in (13) is shown to take on the value zero when

$$y_1 = (1/4 + \alpha/2) \pm \sqrt{\alpha/2} \qquad (0 \leq \alpha < 1/2), \tag{14}$$

and hence (13) is satisfied when the value of y_1 is outside the interval

$\left(\frac{1}{4} + \frac{\alpha}{2} - \sqrt{\frac{\alpha}{2}}, \frac{1}{4} + \frac{\alpha}{2} + \sqrt{\frac{\alpha}{2}}\right)$.

Since only six different sets of values for the arguments of the g function are of interest (cf. (8)), the corresponding six values of α can be denoted as follows:

$$\begin{array}{ll} a_2 + b_1 + b_2 = 1/2 + \alpha_{a_2} & b_1 + a_1 + a_2 = 1/2 + \alpha_{b_1} \\ a_1 + c_1 + c_2 = 1/2 + \alpha_{a_1} & c_2 + b_1 + b_2 = 1/2 + \alpha_{c_2} \\ b_2 + c_1 + c_2 = 1/2 + \alpha_{b_2} & c_1 + a_1 + a_2 = 1/2 + \alpha_{c_1} . \end{array} \tag{15}$$

Observe that $\alpha_{a_1} = -\alpha_{a_2}$, $\alpha_{b_1} = -\alpha_{b_2}$, $\alpha_{c_1} = -\alpha_{c_2}$ and that all the α's are in the interval $(-1/2, 1/2)$.

Theorem 3: If $\alpha_{a_1} = \alpha_{a_2} = \dots = \alpha_{c_2} = 0$, then all the values $a_1, a_2, \dots, c_2$ are equal.

Proof: From (15), $a_1 = b_2$, $a_2 = c_2$, and $b_1 = c_1$.

Substituting a_1 for b_2 in (3), yields

(i) $a_1 = (a_1 + a_2)(2a_1 + b_1)$.

Using the same procedure as above (1 - 6), an inequality analogous to (9) can be derived from (i):

(ii) $(1 - (2a_2 + b_1))^2 - 8a_2b_1 \geq 0$,

which can be rearranged as

(iii) $a_2^2 - (b_1 + 1)a_2 + \left(\frac{b_1 - 1}{2}\right)^2 \geq 0$.

Applying the quadratic formula again results in

(iv) $a_2 \leq 1/2 + \frac{b_1}{2} - \sqrt{b_1}$.

This inequality may also be derived for the pairs $\langle b_1, b_2 \rangle$ and $\langle b_2, a_2 \rangle$, that is

(v) $b_1 \leq 1/2 + \frac{b_2}{2} - \sqrt{b_2}$ and

(vi) $b_2 \leq 1/2 + \frac{a_2}{2} - \sqrt{a_2}$.

The inequalities (iv) - (vi) together with $a_2 + b_1 + b_2 = 1/2$ imply that each of the values a_2, b_1, b_2 is less than .19. For example, if $a_2 = .19$, then (vi) implies $b_2 < .16$, and hence $b_1 = 1/2 - (a_2 + b_2) > .15$. However, $b_1 > .15$ implies $a_2 < .19$ since the function $(1/2 + b_1/2 - \sqrt{b_1})$ is a strictly decreasing function in the interval [0, 1] and its value at $b_1 = .15$ is less than .19. This kind of contradiction can be derived if any of the values in $\mathcal{T}$ is $\geq$ .19. Hence all six values must fall in the interval (.12, .19).

Now it is straightforward to show that (i) implies $a_1 = a_2$. Let $a_2 = a_1 + \varepsilon$ where $0 < |\varepsilon| < .07$. Then

$$\begin{aligned} a_1 &= (a_1 + a_2)(2a_1 + b_1) \\ &= (2a_1 + \varepsilon)(1/2 - \varepsilon) \qquad \text{since } b_1 + a_1 + a_2 = 1/2 \\ &= a_1 + \varepsilon\,(1/2 - \varepsilon - 2a_1) \end{aligned}$$

which implies $(1/2 - \varepsilon - 2a_1) = 0$, and hence $a_1 = 1/4 - c/2 > .215$. Therefore $\varepsilon = 0$ and $a_1 = a_2$. The other equalities are derived similarly. ∎

Thus the assumption that not all values in $\mathcal{T}$ are equal implies that at least one of the α's is greater than zero. For definiteness assume that $\alpha_{a_1} > 0$, and let α denote this particular value. Substituting a_1 for y_1 in (13) yields

$$a_1^{\,2} - (1/2 + \alpha)a_1 + \frac{(1/2 - \alpha)^2}{4} \geq 0 \ , \tag{16}$$

which implies (cf. 14)

$$a_1 \leq (1/4 + \alpha/2) - \sqrt{\tfrac{\alpha}{2}}, \text{ or } a_1 \geq (1/4 + \tfrac{\alpha}{2}) + \sqrt{\tfrac{\alpha}{2}} \ . \tag{17}$$

That is, given the value of $\alpha_{a_1} > 0$, the value of a_1 lies outside an interval of length $\sqrt{2\alpha_{a_1}}$ centered at $(1/4 + \frac{\alpha_{a_1}}{2})$. By the symmetry of the expression in (9), the sum $(c_1 + c_2)$ must also lie outside that interval. For example, if $\alpha_{a_1} = 1/8$, then either $a_1 \leq 1/16$ and $c_1 + c_2 \geq 9/16$ or $a_1 \geq 9/16$ and $c_1 + c_2 \leq 1/16$.

Does this result make a difference? The following detailed example illustrates the implications of (17). It is only loosely analogous to a choice experiment in Luce's sense; however, intuition suggests that axioms pa(1) and pa(2) should hold.

Imagine three barrels, labelled U, V, W, each of which contains ten balls of varying size. Barrel U contains 5 balls of size u_1, 3 balls of size u_2, and 2 balls of size u_3. V contains 4 balls of size v_1, 3 of size v_2, and 3 of size v_3. W contains 1 ball of size w_1, 3 of size w_2, and 6 of

size w_3. The relative sizes of the u, v, and w's are

$$u_1 > v_1 > w_1 > u_2 > v_2 > w_2 > u_3 > v_3 > w_3.$$

An event will consist of drawing three balls, one from each barrel. There are a number of probability functions one could compute in this situation using elementary notions of probability theory (i.e., expressions implied by ca 1-3). Let $q_1(X)$ denote the probability that the ball drawn from the X barrel (X = U, V, or W) is the largest of the three drawn in a given event. Let $q_2(X, Y)$ be the probability that the ball drawn from X is bigger than the ball drawn from Y. And finally, let $q_3(X, Y, Z)$ denote the probability that the sizes of the three balls are ordered $x > y > z$.

The values of the three functions for this example are as follows:

$q_1(U) = .698$	$q_2(U, V) = .740$	$q_3(U, V, W) = .596$
$q_1(V) = .254$	$q_2(U, W) = .890$	$q_3(U, W, V) = .102$
$q_1(W) = .048$	$q_2(V, W) = .850$	$q_3(V, W, U) = .062$
	$q_2(V, U) = .260$	$q_3(V, U, W) = .192$
	$q_2(W, U) = .110$	$q_3(W, V, U) = .006$
	$q_2(W, V) = .150$	$q_3(W, U, V) = .042$

Using the letters $a_1, a_2, \ldots, c_2$ as before, we have $a_1 = .596$, $a_2 = .102$, $b_1 = .062$, and $b_1 + a_1 + a_2 = .76 = 1/2 + .26 = 1/2 + \alpha_{b_1}$. Applying (17) to b_1,

$$b_1 \leq \frac{1}{4} + \frac{.26}{2} - \sqrt{\frac{.26}{2}} \leq .38 - .36 = .02$$

or

$$b_1 \geq \frac{1}{4} + \frac{.26}{2} + \sqrt{\frac{.26}{2}} \geq .38 + .36 = .74$$

However, b_1 does not satisfy either inequality, implying that the functions q_1, q_2, and q_3 do not satisfy axioms pa(1) and pa(2).

For he case being discussed in which at least one of the α's is assumed greater than zero, an even stronger result than (17) can be shown.

Theorem 4: Let $\alpha_{a_1} > 0$. Then given two values a_1 and α_{a_1} (satisfying 17), there exist exactly two combinations of values for a_2, b_1, b_2, c_1, c_2 such that pa(1) and pa(2) are satisfied.

Proof: To show that a_2 depends only upon a_1 and α_{a_1}, combine (7) and (8) to get

$$\text{(i)}\quad a_2 = \frac{1 - (a_1 + c_1 + c_2) \pm \sqrt{(1 - (a_1 + c_1 + c_2))^2 - 4a_1(c_1 + c_2)}}{2} .$$

From (15),

$$\text{(ii)}\quad c_1 + c_2 = 1/2 + \alpha_{a_1} - a_1 .$$

Substituting (ii) into (i) gives

$$\text{(iii)}\quad a_2 = \frac{(1/2 - \alpha_{a_1}) \pm \sqrt{(1/2 - \alpha_{a_1})^2 - 4a_1(1/2 + \alpha_{a_1} - a_1)}}{2} .$$

To derive a formula for c_2, begin again as in (i)

$$\text{(iv)}\quad c_2 = \frac{1 - (c_1 + a_1 + a_2) \pm \sqrt{(1 - (c_1 + a_1 + a_2) - 4c_1(a_1 + a_2)}}{2} ,$$

and substitute (ii) into (iv). The resulting expression can be simplified to

$$\text{(v)}\quad (c_2 + (a_2 + \alpha_{a_1} - 1/2))^2 = (c_2 - (a_2 + \alpha_{a_1} - 1/2))^2 + 4(c_2 + a_1 - \alpha_{a_1})(a_1 + a_2).$$

The squared terms cancel in (v), which can then be solved for c_2:

$$\text{(vi)}\quad c_2 = \frac{(1/2 + \alpha_{a_1} - a_1)(a_1 + a_2)}{(1/2 - \alpha_{a_1} + a_1)} .$$

Solving (ii) for c_1 gives

$$\text{(vii)}\quad c_1 = 1/2 + \alpha_{a_1} - a_1 - c_2 .$$

Formulas for b_2 and b_1 are derived in a similar way, using another equation from (15)

$$\text{(viii)}\quad b_1 + b_2 = 1/2 - \alpha_{a_1} - a_2 :$$

$$\text{(ix)}\quad b_2 = \frac{(1/2 - \alpha_{a_1} - a_2)(a_1 + a_2)}{(1/2 + \alpha_{a_1} + a_2)} .$$

Observe that two values are generated for a_2, but that for each of those values there is a unique set of values for b_1, b_2, c_1, and c_2. ∎

As an example of a set of values obtainable according to the formulas in theorem 4, let $a_1 = 7/64$ and $\alpha a_1 = 1/32$. Then

$$a_2 = \frac{9}{64} \quad b_1 = \frac{21\cdot 27}{43\cdot 64} \quad b_2 = \frac{21}{43\cdot 4} \quad c_1 = \frac{21\cdot 27}{37\cdot 64} \text{ and } \quad c_2 = \frac{27}{37\cdot 4},$$

or

$$a_2 = \frac{21}{64} \quad b_1 = \frac{9\cdot 27}{55\cdot 64} \quad b_2 = \frac{9\cdot 28}{55\cdot 64} \quad c_1 = \frac{27\cdot 9}{37\cdot 64} \text{ and } \quad c_2 = \frac{27\cdot 28}{37\cdot 64}.$$

Consider now a model-theoretic framework in which the theorems proven above in the axiomatic choice theory can be discussed. The first step is to define a first-order language L adequate to express the axioms and theorems. L will contain the following components:

(a) Relation symbols to represent $\geq$, $\mathbb{R}$

(b) Function symbols with the appropriate number of arguments for the probability functions P_A, p, $\bar{p}$, P_A^*, p^*, $\bar{p}^*$

(c) Function symbols for $+$, $-$, $\cdot$, $\div$, $\sqrt{\ }$

(d) Constant symbols for 0, 1

(e) Variables $x_1, x_2, \ldots$

(f) Logical connectives $\neg$, $\vee$, $\wedge$, $\supset$, $=$

(g) Quantifiers $\forall$, $\exists$.

$\mathbb{R}$ is the set of real numbers and "=" is treated as a logical connective meaning identity. A relation symbol for $\mathbb{R}$ is needed so that the sets A and $\mathbb{R}$ can be distinguished, that is, so that variables can be quantified over just A or just $\mathbb{R}$. Generally the logical symbols remain implicit and L may be described by writing a vector of non-logical symbols, analogous to the notation for structures. (Function symbols will have a superscript denoting the number of arguments f^n, even though f^n represents an $n + 1$ place relation.) The language L is given by

$$L = \langle R_1^2, R_2^1; f_1^1, f_2^2, f_3^3, f_4^1, f_5^2, f_6^3, f_7^2, f_8^2, f_9^2, f_{10}^2, f_{11}^1; c_1, c_2 \rangle$$

where the symbols are written in order corresponding to the order of their intended interpretations in (a) - (d) above. That is, R_1^2 corresponds to "$\geq$", f_4^1 to "P_A^*", f_7^2 to "+", etc.

As an example of a formal sentence in L, the decomposition axiom pa(i) can be translated

pa(1): $(\forall x_1)(\forall x_2)(\forall x_3)[(\neg x_1 = x_2 \wedge \neg x_1 = x_3 \wedge \neg x_2 = x_3 \wedge \neg R_2^1(x_1) \wedge \neg R_2^1(x_2) \wedge \neg R_2^1(x_3)) \supset f_3^3(x_1, x_2, x_3) = f_9^2(f_1^1(x_1), f_2^2(x_2, x_3))]$.

In addition to pa(1) - (2) there are a number of implicit and explicit assumptions employed in the first part of this section which should be stated as proper axioms. Implicit are all the field axioms for real numbers such as associativity, distributivity, existence of 0 and 1, and the basic axioms for an order relation. These will be referred to as the axioms for an ordered field. Second, it was assumed that the set A contained exactly three elements, and further that the square root function was defined only on nonnegative numbers. These axioms may be written as follows:

pa(4) Axioms for ordered field

pa(5) $(\exists x_1)(\exists x_2)(\exists x_3)[(\neg x_1 = x_2 \wedge \neg{}_1 = x_3 \wedge \neg x_2 = x_3 \wedge \neg R_2^1(x_1) \wedge \neg R_2^1(x_2) \wedge \neg R_2^1(x_3) \wedge (\forall x_4)(\neg R_2^1(x_4) \supset (x_4 = x_1 \vee x_4 = x_2 \vee x_4 = x_3))]$

pa(6) $(\forall x_1)(\forall x_2)(R_2^1(x_1) \wedge R_2^1(x_2) \supset (f_{11}^1(x_1) = x_2 \supset x_i R_1^2\ c_1))$.

For the remainder of this section the notation $T(1_i, \ldots, i_k)$ will denote the subset of proper axioms consisting of $\{pa(i_1), \ldots, pa(i_k)\}$.

The notion of "intended interpretation" is made precise by defining a class of structures $\mathcal{M}_0$ whose members contain the particular functions and relations used in the analysis of this section. Let $\mathcal{M}_0$ be the collection of M's such that

$$M = \langle A \cup \mathbb{R} ; \geq , \mathbb{R}_2 ; P_A, P, \bar{P}, P_A^*, P^*, \bar{P}^*, +, -, \cdot, \div, \sqrt{\ } ; 0, 1 \rangle.$$

A is any three-element set, $\mathbb{R}_2$ is the membership relation on $\mathbb{R}$, P_A (and P_A^*) maps A into $\mathbb{R}$, p (and p^*) maps A x A into $\mathbb{R}$, $\bar{p}$ (and $\bar{p}^*$) maps A x A x A into $\mathbb{R}$, and the remaining functions and constants are defined on $\mathbb{R}$. That is, for any interpretation φ of sentences in L into a structure in $\mathcal{M}_0$, $\varphi(R_1^{\ 2}) = \geq$, $\varphi(R_2^{\ 1}) = \mathbb{R}_2$, $\varphi(f_7^{\ 2}) = +$, $\varphi(f_{11}^{\ 1}) = \sqrt{\ }$, $\varphi(c_1) = 0$, etc. Thus two structures M and M' in $\mathcal{M}_0$ differ only in the six "p" functions and in the choice of set A.

Within the class $\mathcal{M}_0$ there are structures which satisfy some of the various subsets of T(1,..., 6). $\mathcal{M}_0$ has been defined such that each M in $\mathcal{M}_0$ satisfies T(4, 5, 6). The structure defined in the barrel example, $M_b = \langle \{U, V, W\} \cup \mathbb{R}; \geq, \mathbb{R}_2, q_1, q_2, q_3, +, \ldots \rangle$, satisfies T(2, 4, 5, 6), but does not satisfy T(1, 2, 4, 5, 6). Theorem 2 states that any structure in $\mathcal{M}_0$ satisfying T(1,..., 6) must be one in which $P_A(x) = 1/3$ for all arguments x, p(x, y) = 1/2 for all x,y , and $\bar{p}(x, y, z) = 1/6$ for all x, y, z. Hence any two such structures M and M', since they differ only in having different sets A, A', are isomorphic. Thus the axiom set T(1,..., 6) has essentially one model in $\mathcal{M}_0$. Restated in this way Theorem 2 does not seem anomalous or contrary to experience. Similarly, Theorem 4 characterizes the subclass of $\mathcal{M}_0$ whose elements are models of T(1, 2, 4, 5, 6), and this subclass is also very small relative to $\mathcal{M}_0$.

Conclusion

At the end of the previous section, the class of models for the axiom set T(1, 2, 4, 5, 6) was described as being small compared to $\mathcal{M}_0$, even though both ar countably infinite classes. In order to make sense out of that statement consider the inequality (17). It implies that for

two specific values such as $\bar{p}(a, b, c)$ and $P_A(c)$, if their sum is greater than 1/2 by an amount α, then there is a subinterval or "hole" in the interval (0, 1) which must not contain either $\bar{p}(a, b, c)$ or $P_A(c)$. In fact, the size of that hole is given precisely as $\sqrt{2\alpha}$. However since the value of α depends upon the values of $\bar{p}$ and P_A, there is no fixed α which applies to all structures in $\mathcal{M}_0$, and thus (17) only gives a rough idea of the restrictions imposed by the axioms.

A better, but still intuitive, approximation on the relative size of the class of models can be derived from theorem 4. It states that only two probability values(which satisfy (17), e.g., $\bar{p}(a, b, c)$ and $P_A(c)$) need be known inorder to compute all the remaining values in a model. For an arbitrary structure in $\mathcal{M}_0$, however, five values for $\bar{p}$ would be needed in order to compute the sixth value using ca(2). In a very loose way, the class of models could be thought of as less than two-fifths the size of $\mathcal{M}_0$. Thus it would seem that these axioms put "more" constraints on the way choice probabilities may be related than has previously been thought to be the case.

As pointed out in the first section, the scarcity of models for an axiom set usually has led to attempts to identify "troublesome" axioms and remove them from the theory under consideration. However, that approach sometimes causes the loss of useful theorems (theorem 1, in our example). The point here is not whether it is desirable to have few or many models for a theory, but rather to offer an alternative to the axiom-elimination approach. In model-theoretic terms, that alternative is to enlarge or change the class of structures in which models may be sought.

Consider just the axioms pa(1) and pa(2) for a moment. The non-logical functions involved are just P_A, p, $\bar{p}$, +, and $\cdot$. The p functions must map into a set containing elements like 0 and 1 and a relation $\geq$ which has some order properties, in order to satisfy the calculus axioms, but otherwise there is no a priori restriction on how we might interpret those functions. A very large (with respect to $\mathcal{M}_0$) class $\mathcal{M}$ of structures could be defined as the class of M such that

$$M = \langle A \cup D; \geq, D_1; P_A, p, \bar{p}, +, \cdot; 0, 1\rangle$$

where A and D are two disjoint sets, D contains at least two distinct elements which we call 0, 1, P_A maps A into D; p maps A x A into D; $\bar{p}$ maps A x A x A into D; + and $\cdot$ are any two binary operations on D; $\geq$ is a binary relation in D; and D_1 indicates membership in D.

An example of such a structure is one in which D is the set of complex numbers, and the values of the function $\bar{p}$ (again denoted by $a_1, \ldots, c_2$) are

$$a_1 = \frac{3}{8} \qquad b_1 = \frac{-1 - 16\sqrt{21}}{152} \qquad c_1 = \frac{3 - 6\sqrt{21}}{40}$$

$$a_2 = \frac{1 + 2\sqrt{21}}{8} \qquad b_2 = \frac{10 - 11\sqrt{21}}{76} \qquad c_2 = \frac{12 + 6\sqrt{21}}{40}$$

For these values, ${}^{\alpha}a_1 = 1/4$, which implies that a_1 is in one of the "holes" described above. Thus theorems 3 and 4 do not characterize the models of T(1, 2) in the class $\mathcal{M}$, and the class of models for T(1, 2) within $\mathcal{M}$ properly contains the corresponding class of models within $\mathcal{M}_0$. Finally we emphasize that it is questions such as these concerning the relationships between classes of set-theoretic structures to which the methods of mathematical model theory may be applied.

Footnotes

1. The research for this article was partially supported by NSF Grant GS 2955 and by ARPA Contract DAHC 1573-C-0197.

References

Block, H.D. & Marschak, J. Random orderings and stochastic theories of responses. In I. Olkin, S. Ghurye, W. Hoeffding, W. Madow, & H. Mann (Eds.), Contributions to probability and statistics. Stanford: Stanford University Press, 1960. Pp. 97-132.

Braithwaite, R.B. Models in the empirical sciences. In E. Nagel, P. Suppes, & A. Tarski (Eds.), International congress of logic, methodology and the philosophy of science. Stanford: Stanford University Press, 1960.

Luce, R.D. Individual choice behavior. New York: Wiley & Sons, 1959.

Luce, R.D. & Suppes, P. Preference, utility, and subjective probability. In R.D. Luce, R.R. Bush, & E. Galanter (Eds.), Handbook of mathematical psychology, v. 3. New York: Wiley & Sons, 1965. Pp. 249-410.

Quine, W.V. Replies to Chomsky. Synthese, 1968-69, v. 19, 274-283.

Robinson, A. Introduction to model theory and to the metamathematics of algebra. Amsterdam: North-Holland, 1963.

Tarski, A. The semantic conception of truth. Philosophy and Phenomonological Research, 1944, v. 4, 341-375.

Tversky, A. Elimination by aspects: A theory of choice. Psychological Review, 1972, v. 79, 281-299.

Some Generalizations of Social Decisions
Under Majority Rule*

R.E. Wendell
School of Urban and Public Affairs
Carnegie - Mellon University

S.J. Thorson
Project for Theoretical Politics
Polimetrics Laboratory
Department of Political Science
Ohio State University

Project Research Paper No. 8

*The research described in this paper was in part supported by ARPA Contract No. DAHC 15 73 C 0197. A version of this work was presented at the 1973 Annual Meetings of the Midwest Political Science Association.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Project for Theoretical Politics The Ohio State University 053 Administration Building	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

"Some Generalizations of Social Decisions Under Majority Rule"

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Research Report # 8

5. AUTHOR(S) (First name, middle initial, last name)

Stuart J. Thorson

Richard E. Wendell

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 30, 1973	41	34

8a. CONTRACT OR GRANT NO. DAHC15 73 C 0197 b. PROJECT NO. A.O. 2345-3D20 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) # 8 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited and production in whole or in part is permitted for any purpose of the United States Government.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Advanced Research Projects Agency Washington, D.C.

13. ABSTRACT

The existence of equilibrium points under majority rule is investigated for an n-dimensional issue space and an expanded class of indifference contours. This paper generalizes previous problem formulations and results.

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Decision theory						
Spatial theory						
Democracy						
Majority rule						
Location theory						

In recent years considerable theoretical effort has been centered on determining the existence and location of an optimal group decision or position on the basis of a variety of assumptions about the preferences of the individuals in the group. Such results as have been previously obtained suggest possible applications in phenomena ranging from small group and committee decision making to electoral strategy at the national level. Unfortunately, the applicability of previous results has been limited by the rather restrictive assumptions required to derive them. In this paper we propose a generalized theory of optimal decisions under majority rule which is based upon assumptions which are considerably less restrictive than those made in previous work.

Prior results then become important special cases of the general theory presented here. For example, it has already been shown that when only one issue exists, then the median position of the citizen's preferences on this issue has the property that no other issue position will be strictly preferred to it by a majority of the citizens (or members of the group). In the case of more than one issue, various symmetry and indifference contour assumptions have led to the result that the mean is such an "unbeatable point." For a further discussion on the history and the details of the above results see (for example) [6] and [18]. We will, however, review in more detail the formulation and results alluded to above in the next section. Furthermore, we will study a more general class of indifference contours. In particular, this class contains the "Euclidian contours" of [6] and [18] as a special case. With respect to this class of indifferent contours we generalize the median result in the one issue case to the case where the

position of all the citizens lies along some line in a multi-issue space. Then we consider special cases of our general indifferent contour class which are just as important (if not more so) than the "Euclidian contours." With respect to these special cases, we also generalize the median result from the one issue case to the two dimensional issue case. Furthermore, this generalization is made without symmetry assumptions. Finally, as in [6], we compare our results to those that result from a benevolent dictator analysis [23]. In conclusion, this paper is a generalization of not only the problem formulation but of well established results in the literature on optimal decisions under majority rule.

1. A Review of Spatial Theory and Democracy Analysis

Following [6] we consider a situation in which there are n (finite) issues and m (finite) citizens. Letting each of the n coordinate axes* of R^n correspond to an issue we can represent the location of each citizen $x_i (i=1,\dots,m)$ in the issue space R^n. In particular,** $x_i = (x_i^1, x_i^2, \dots, x_i^n)' \epsilon R^n$ is the (unique) most preferred position of citizen i in the issue space. Now consider an arbitrary position $\theta = (\theta^1, \theta^2, \dots, \theta^n)' \epsilon R^n$. With respect to position θ and each citizen i we define:

$L_i(\theta) \equiv$ the loss citizen i sustains from the position θ.

In particular, $L_i(\theta)$ is a function from R^n into R^1.

To characterize the phenomena that citizen i becomes "less happy" as the "distance" between θ and x_i increases, we make the following assumption of "single peakedness" for each citizen's loss function:

(1.1) For every non-zero vector $v \epsilon R$ and every pair of scalars $\lambda_1, \lambda_2 \geq 0$ such that $\lambda_1 > \lambda_2$, we require $L_i(x_i + \lambda_1 v) > L_i(x_i + \lambda_2 v)$.

In the above assumption note that $x_i + \lambda v$ defines a ray with an origin at x_i and direction v. Thus, the assumption has an interpretation of an increasing loss to each citizen i as we move farther from x_i along any ray. This is equivalent to the "single peakedness" assumption in [6].

We can now more meaningfully discuss the central point of this paper. In particular, we can now define what we mean by "best position" under majority rule. In our discussion such a position will be called an <u>equilibrium point</u>. Further, we distinguish different types of equilibrium points in the following definition.

<u>Definition 1.1</u>

Consider a point $\theta^* \epsilon R^n$. For each $\theta \epsilon R^n$ define:

$p(\theta) \equiv$ the number of citizens who have $L_i(\theta^*) < L_i(\theta)$;

$q(\theta) \equiv$ the number of citizens who have $L_i(\theta^*) > L_i(\theta)$;

$r(\theta) \equiv$ the number of citizens who have $L_i(\theta^*) = L_i(\theta)$;

so that $p(\theta) + q(\theta) + r(\theta) = m$.

(i) If for every $\theta \epsilon R^n$ we have $p(\theta) \geq m/2$, then we say that θ^* is a <u>majority equilibrium point</u>.*

(ii) If for every $\theta \epsilon R^n$ we have $p(\theta) \geq q(\theta)$, then we say that θ^* is a <u>plurality equilibrium point</u>.*

(iii) If for every $\theta \epsilon R^n$ we have $p(\theta) + r(\theta) \geq m/2$, then we say that θ^* is a <u>non-minority equilibrium point</u>.

Note that any θ^* satisfying (i) will also satisfy (ii) and, similarly, any θ^* satisfying (ii) will satisfy (iii). Also note that with respect to any of the three types of equilibrium points we can consider the case where it is unique. In (i), for example, θ^* is unique if for every $\theta \neq \theta^*$ we have $p(\theta) > m/2$. Similarly in (ii) θ^* is unique if for every $\theta \neq \theta^*$ we have $p(\theta) > q(\theta)$. For a discussion of (iii) and its uniqueness properties we refer the reader to [5]. For our purposes, (iii) has some undesirable properties (e.g., see footnote 2 on page 150 of [5]) and we will not further consider it in this paper.

---

*The set R is the set of all real numbers. The set R^n is the Cartesian product of "n" sets equal to R; i.e., RxRx ... xR. Any point on R^n is then an n-tuple of real numbers.

**We use the notation "'" to denote the transpose of a vector.

*Note that our use of the word "plurality" is somewhat different than usual. In particular, our use has an interpretation as a majority of those citizens who are not indifferent.

In the spatial theory literature the concept of an equilibrium point is often referred to as a dominant point. To be consistent with other literature [15], [23], we will later use dominant to have a somewhat different meaning.

We will now interpret the above definitions in a voting situation between positions θ_1 and θ_2 in R^n. To do this we make the following assumption.

(1.2) Each citizen i votes for θ_1 iff (i.e., if and only if) $L_i(\theta_1) < L_i(\theta_2)$ and, similarly, votes for θ_2 iff $L_i(\theta_2) < L_i(\theta_1)$.

Thus, if $L_i(\theta_1) = L_i(\theta_2)$, citizen i is indifferent between θ_1 and θ_2 and he will not vote. Hence, if θ_1 is a majority equilibrium point, then at least one half of the citizens will always vote for θ_1 in any election regardless of the position of θ_2. If θ_1 is at a unique majority equilibrium point and if $\theta_2 \neq \theta_1$, then more than one half of the citizens will vote for θ_1 over θ_2. Similarly, if θ_1 is at a plurality equilibrium point, then θ_1 will always obtain at least as many votes as θ_2 (but because of indifferences not necessarily a majority of all citizens). If further θ_1 is a unique plurality equilibrium point and if $\theta_1 \neq \theta_2$, then θ_1 will obtain more votes than θ_2. It is perhaps appropriate to point out that positions θ_1 and θ_2 are often interpreted to represent the locations of two candidates in the issue space.

Again following [6] we let $f(x)$ denote a multivariate density of preference "which characterizes the population in the sense that it represents a summary statement of the preferred positions of all citizens."

With respect to the above notation, we have the following important result in the one issue (R^1) case.

Theorem 1.1. Consider the case of just one issue. If θ^* is a median of $f(x)$ and if (1.1) holds, then θ^* is a majority equilibrium point. If further the median is unique (e.g., as in the case where m is odd), then θ^* is the unique majority equilibrium point.

The simple proof of this theorem is given on page 427 of [6].

The above result tends to strongly imply that candidates should locate at median positions on issues. This unfortunately is not in general true. Consider, for example, a situation of three citizens in a two-dimensional issue space whose loss functions have the form

$$L_i(\theta) = [(x_i^1 - \theta^1)^2 + (x_i^2 - \theta^2)^2]^{\frac{1}{2}}$$

(the usual Euclidian norm). Then for the situation illustrated in Figure 1.1, (insert Figure 1.1) where θ_1 corresponds to the median position on each issue and the circles are isoloss* contours, we can readily see that θ_2 is strictly preferred to θ_1 by citizens 1 and 2. Furthermore, θ_3 is strictly preferred to θ_2 by citizens 2 and 3 while θ_1 is strictly preferred to θ_3 by citizens 1 and 3. From this we can conclude that the "multidimensional median" θ_1 is not in general an equilibrium point. Furthermore, this same construction can be used to show that in general no equilibrium point θ^* need exist in a multidimensional issue space [6].

This does not, however, imply that equilibrium points cannot exist in multidimensional issue spaces. We will now review some conditions which guarantee the existence of an equilibrium point.

Again following [6] suppose that

$$L_i(\theta) = \phi((x_i-\theta)' A(x_i-\theta)) \tag{1.3}$$

where $\phi(.)$ is a strictly increasing function and A is a positive definite

*See Section 2 for a precise definition of this concept.

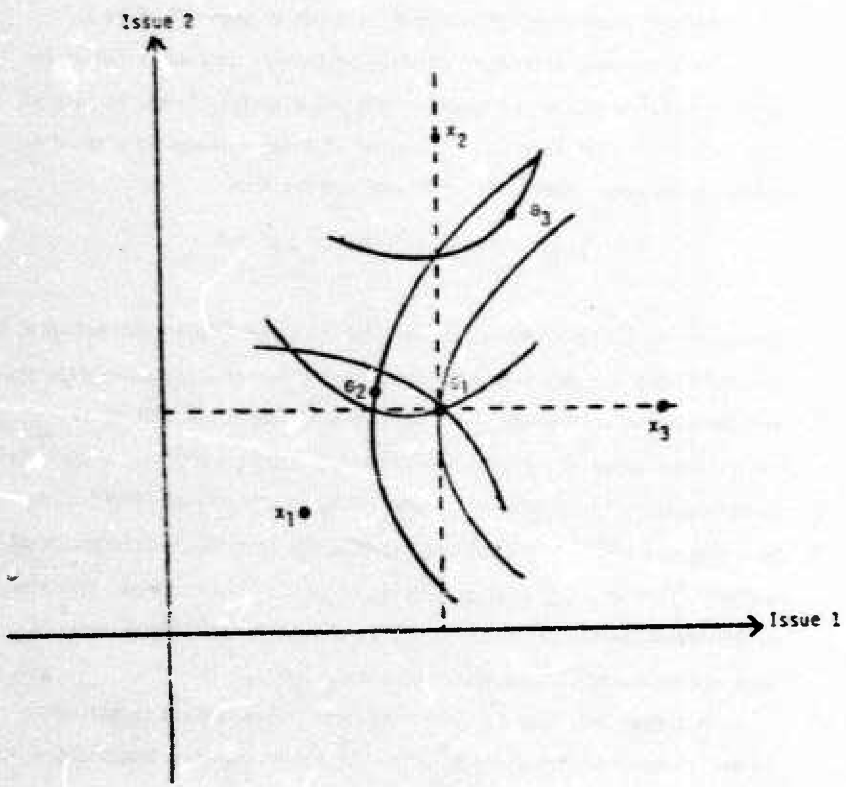


Figure 1.1

matrix (one can easily show that (1.1) is satisfied in this case). This yields isoloss contours that have the shape of a rotated ellipse about each citizen i. This is illustrated in Figure 1.2. (Insert Figure 1.2). Since each citizen's loss function is defined by the same matrix A, the shape of the isoloss contours are implicitly assumed to be the same for all citizens.

Besides the assumptions implicit in the expression (1.3), following [6] we also assume that $f(x)$ is symmetric about some point θ^*. In that case, they prove that θ^* is an equilibrium point. We now state this result more precisely.

Theorem 1.2. If $f(x)$ is symmetric about θ^* and if each citizen's loss function has the form (1.3), then θ^* is a unique plurality equilibrium point.

Note that θ^* is the mean of $f(x)$. Thus, in contrast to the median results in Theorem 1.1, Theorem 1.2 gives conditions when the mean is an equilibrium point.

Before studying other multidimensional equilibrium existence questions, we first take a more detailed look at the nature of isoloss contours.

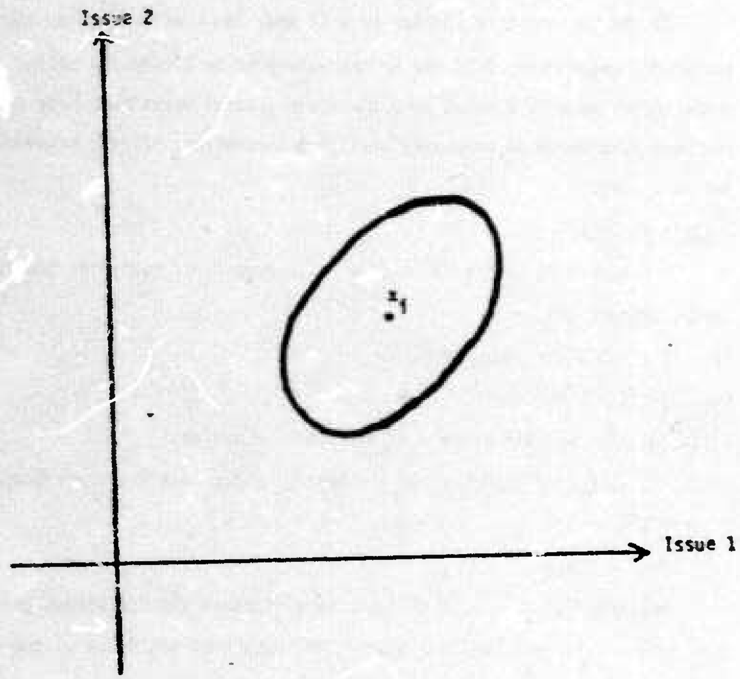


Figure 1.2

2. Indifference Contours and Norms

By an indifference contour for a citizen i we mean the locus of points about his position x_i over which he is indifferent. In Section 1 we called such a set of points an isoloss contour for citizen i. Figure 2.1a illustrates a general indifference contour for citizen i.

Consider a set of points S_I enclosed by an indifference contour I (see Figure 2.1).(insert Figure 2.1). Such a set S_I will either be convex* or nonconvex. Figure 2.1a illustrates a nonconvex set S_I while Figure 2.1b illustrates a convex set S_I. In this paper we restrict our analysis to the cases where S_I is convex. This restriction is analogous to the usual behavioral assumption of diminishing marginal rate of substitution in economics [3].

Another property that indifference curves may have is symmetry about the citizen's position x_i. More specifically, an indifference curve I for citizen i is said to be symmetric about x_i if for every $c \in I$, $2x_i - c$ is also on I. An example of a symmetric indifference curve is given in Figure 2.1c. Although symmetric indifference contours constitute a special class of contours, we will limit our discussion in this paper to them.

In summary, we consider the following class of indifference contours in this paper.

(2.1) For each citizen i we assume that each of his indifference contours

*A set S is convex if the points on a line segment connecting any two points of the set are also in S.

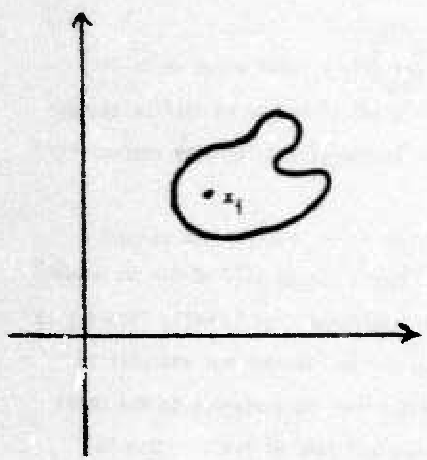


Figure 2.1a

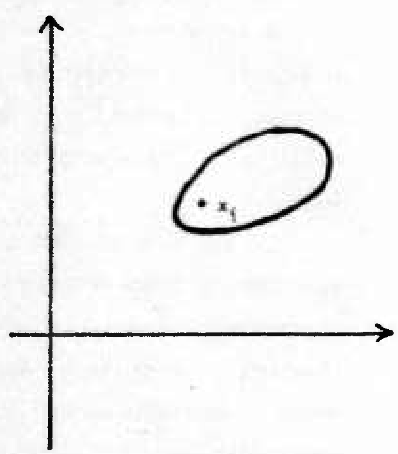


Figure 2.1b

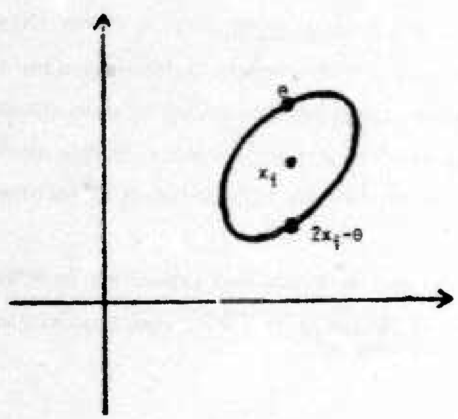


Figure 2.1c

I is symmetric about the position x_i and that each corresponding set S_I is convex.

Note that the elliptical indifference contours considered in [6] (e.g. as discussed in Section 1) satisfy assumption (2.1).

In the rest of this section we will show how indifference contours satisfying assumption (2.1) can be characterized by a function called a norm. Also, we will discuss some important special norms that have not yet been considered in democracy equilibrium problems. First, however, we define a norm.

<u>Definition 2.1</u>.

A function $||\cdot||$ from R^n into R^1 is a norm if it satisfies the following properties:

(i) $||\xi|| \geq 0$ for every $\xi \epsilon R^n$;

(ii) $||\xi|| = 0$ iff $\xi = 0$;

(iii) $||a\xi|| = a||\xi||$ where a is any positive scalar;

(iv) $||\xi_1 + \xi_2|| \leq ||\xi_1|| + ||\xi_2||$ where ξ_1 and ξ_2 are arbitrary vectors in R^n;

(v) $||\xi|| = ||-\xi||$.

Property (i) says that the norm is a function that is always greater than or equal to zero, while property (ii) says that the value of the norm is zero iff $\xi = 0 \epsilon R^n$. Property (iii) is a linear homogeneity property and property (iv) is often called the triangle inequality. Finally, property (v) is just one of symmetry.

Before giving some examples to illustrate functions which are norms, we first try to motivate our discussion. Consider the locus of those points θ that yield the same value for the function $||\theta - x_i||$. This locus of points will be called an <u>indifference contour about x_i under the norm</u>

$||\cdot||$. Now we can state the following important result.

Theorem 2.1. To each indifference contour I for citizen i that satisfies assumption (2.1) there exists some norm $||\cdot||$ such that $||\theta - x_i||$ generates the same indifference contour about x_i. Conversely, every indifference contour about x_i generated by a norm $||\cdot||$ satisfies the assumptions in (2.1).

(See Theorem 15.2 of [19] for a proof of this equivalence between norms and sets S_I having the properties resulting from assumption (2.1)).

The above theorem essentially says that the class of indifference curves satisfying (1.2) is equivalent to the class of functions that are norms. More specifically, any indifference curve satisfying the assumptions in (2.1) corresponds to some norm $||\cdot||$ and every norm generates indifference curves that satisfy (2.1). We now consider some particular norms that may have important interpretations in political theory.

Example 2.1.

Consider a norm defined as

$$(2.2) \qquad ||\xi|| = [\xi' A \xi]^{\frac{1}{2}}$$

where A is a positive definite matrix. For reasons to be explained below, we call this the "generalized" Euclidian norm. See Householder [12] to see how (2.2) satisfies the properties in Definition 2.1. As we will see, this norm is precisely the one considered in previous spatial theory articles [6], [18]. In fact, the shape of its indifference contours (e.g., in R^2) is that of a rotated ellipse.

For our purposes, it is important to point out that since A is positive definite one can find the eigenvectors of A and then use these vectors as a new coordinate system for the issue space. Furthermore, by making appropriate scaling changes along each of the new axes we get the

following equivalent norm to (2.2) (i.e., details of this equivalence are given in [6] and [18]):

$$(2.3) \qquad ||\xi|| = [\xi'\xi]^{\frac{1}{2}}$$

The norm in (2.3) is just the well known Euclidian norm which we will refer to as the ℓ_2 norm (for reasons to become clearer later) and we distinguish it from other norms by writing $||\cdot||^{(2)}$ (i.e., $||\xi||^{(2)} = [\xi'\xi]^{\frac{1}{2}}$). Note that the indifference contours for the Euclidian norm (2.3) are now "circles" instead of the "ellipses" as in (2.2). From this difference one can observe that the above transition from (2.2) to (2.3) involved essentially a rotation and scaling change of the axes. Furthermore, we can conclude that the norm in (2.2) is mathematically no more general than the well known Euclidian norm (2.3).

By letting $\xi = x_i - \theta$ in (2.2) we get

$$(2.4) \qquad ||x_i - \theta|| = [(x_i-\theta)' A (x_i-\theta)]^{\frac{1}{2}} .$$

Except for the square root, (2.4) is identical to the argument of ϕ in (1.3). Thus, one can see that the indifference contours to (1.3) have the same shape as that in (2.4). In particular, this is illustrated in Figure 1.2. Of course, under an appropriate basis change (as discussed above)(2.4) is equivalent to the Euclidian norm

$$(2.5) \qquad ||x_i - \theta||^{(2)} = [(x_i-\theta)'(x_i-\theta)]^{\frac{1}{2}}$$

whose indifference contours are "circles" about x_i.

Example 2.2

Consider a norm defined as

$$(2.6) \qquad ||\xi||^{(1)} = \sum_{j=1}^{n} |\xi^j|$$

where $\xi \epsilon R^n$ (the superscript (1) is used to denote this type of norm).

The fact that (2.6) indeed satisfies the properties in Definition 2.1

is easy to prove. Such a norm is often called the city block norm, the Manhattan norm, or the ℓ_1 norm. The reason for the former names is that in various urban areas (e.g., Manhattan) the city streets are in the north-south and east-west directions. Given a north-south and east-west coordinate system, a distance vector ϵ has a length given by the sum of absolute values of the coordinates. This is illustrated in Figure 2.2. (insert Figure 2.2). The reason for it being called the ℓ_1 norm will become clear in Example 2.4.

Besides the above interpretation, the ℓ_1 norm has an interesting interpretation in distance perception in an issue space. Consider a citizen's position at a point x_i and a candidate's position at the point θ. Then

$$||\theta-x_i||^{(1)} = \sum_{j=1}^{n} |\theta^j-x_i^j|$$

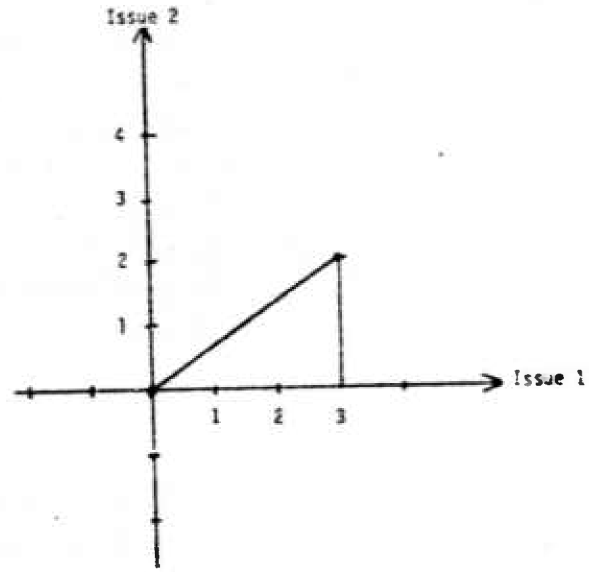
and the citizen views the distance from him to the candidate as the sum of the distance that their views vary on each issue.

Since the empirical work of Attneave [2], the ℓ_1 norm has been of some interest to psychologists in analyzing perceptual data. Indeed the argument has been made [2] that the ℓ_1 norm rather than the Euclidian norm should be considered as fundamental for ordering perceptual data, since subjects seemed to judge dissimilarities in geometric stimuli by independently judging differences in components (dimensions). Further, the ℓ_1 norm has nice additive properties not possessed by the Euclidian norm. Indifference contours of this type of individual are given in Figure 2.3. Note the diamond shape of these contours as opposed to the elliptical shape in Example 2.1. (insert Figure 2.3).

<u>Example 2.3</u>

Consider a norm defined as

$$||\epsilon||^{(\infty)} \equiv \max_{j=1,\ldots,n} \{|\epsilon^j|\} \tag{2.7}$$



$$||\epsilon||^{(1)} = |3| + |2| = 3 + 2 = 5$$

$$||\epsilon||^{(2)} = [(3)^2 + (2)^2]^{1/2} = [13]^{1/2}$$

$$||\epsilon||^{(\infty)} = \mathrm{Max}\{|3|,|2|\} = 3$$

Figure 2.2

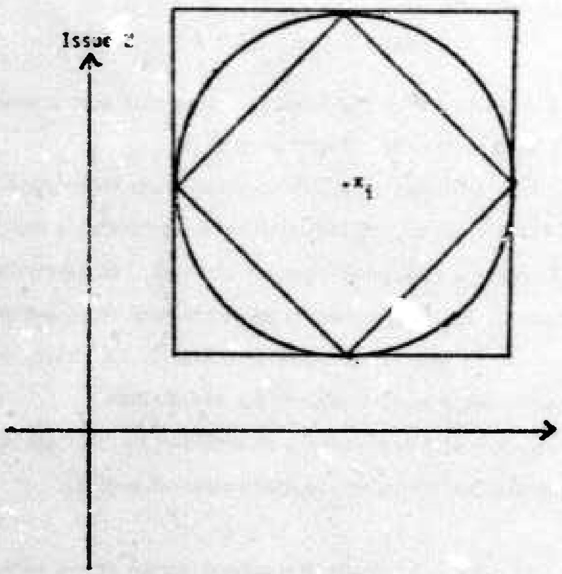


Figure 2.3

where $\xi \epsilon R^n$ (the superscript ∞) is used to denote this type of norm).

Such a norm is often called the sup norm, the Tchebycheff norm, or the ℓ_∞ norm. Unlike the previous norm, the ℓ_∞ norm has an interpretation that the distance from a candidate to a citizen equals the maximum of the differences in positions over all issues. Mathematically, we write this as

$$||\theta - x_i||^{(\infty)} = \max_{j=1,\ldots,n} \{|\theta^j - x_i^j|\}.$$

This is illustrated numerically in Figure 2.2.

This norm might well be of special interest in political science. In particular, a citizen who measures distance under such a norm would ignore a candidate's position on all issues but the one which achieved **maximum** disparity (e.g., Vietnam).

As shown in Figure 2.3, the indifference contours for this type of norm are box-like. Since a rotation of the box is a diamond, one might suspect that the mathematical structure of ℓ_1 persons and ℓ_∞ persons is related. We will now investigate this relationship between these two norms.

Theorem 2.2. In R^2 the ℓ_1 norm and the ℓ_∞ norm are equivalent under a change of variables (i.e., a 45 degree rotation).

For a proof, see [29].

Just as significant as the above theorem is the fact that the norms are not equivalent in R^n for $n \geq 3$. In R^3, for example, the diamond will have 6 extreme points (e.g., corners) while a box has 8 extreme points. Thus, no matter how much one rotates the two figures, they will never become "equivalent."

Example 2.4

In a more general sense we define an ℓ_p norm for $p \geq 1$ as

$$(2.8) \qquad ||\varepsilon||^{(p)} \equiv \left[\sum_{j=1}^{n} |\varepsilon^j|^p \right]^{1/p} ,$$

where superscript (p) is used to denote the particular ℓ_p norm. It is not especially easy to see that (2.8) defines a norm and, in particular, we must apply the Minkowski inequality to prove the triangle inequality in Definition 2.1. Note that Examples 2.1 and 2.2 are special cases when p=2 and 1, respectively. It can also be shown that Example 2.3 is a special case when $p=\infty$ [12].

To observe how the norm given in (2.2) is such a special case, note that its equivalent form (2.3) is just a special case of the ℓ_p norm when p=2. Thus, the norm previously considered in spatial theory analysis is just one of an (uncountably) infinite number. Furthermore, even ℓ_p norms do not exhaust all possible types. This is easily seen from the fact that

$$||\varepsilon|| \equiv ||\varepsilon||^{(1)} + ||\varepsilon||^{(2)}$$

is a norm that is not equivalent to any ℓ_p norm. Finally, we end this section with the following observation: althouth the ℓ_p norms can be "generalized" to allow for basis changes which correspond to rotations and scale changes (as in Example 2.1), we will, for simplicity, stick to the matheratically equivalent forms that are given in the Examples.

3. Equilibrium Points in a Generalized Spatial Approach

Now that we know what a norm is, we will let $||\cdot||_i$ denote a norm whose type is allowed to depend on the citizen i. For example, citizen 1 may measure distance via the ℓ_1 norm, citizen 2 may use the ℓ_2 norm, and citizen 3 may use the ℓ_∞ norm. In general, we assume that each citizen's loss function has the form

$$(3.1) \qquad L_i(\theta) = C_i(||x_i-\theta||_i)$$

where $C_i(.)$ is a strictly increasing function. Note that such a formulation satisfies the "single peakedness" condition in (1.1).

If we just have one issue (i.e., n=1), then we are in the case considered by Theorem 1.1. If, on the other hand, we have more than one issue, then (3.1) results in a generalization of (1.3). In particular, if all of the norms $||\cdot||_i$ are assumed to be of the form (2.2) and if $C_i(z) = \phi(z^2)$ for all i, then (3.1) degenerates into (1.3). Thus, previous spatial analysis becomes a special case of our formulation.

Before proceeding with our analysis of majority decision making, we will first review the definition of a multidimensional median.

Definition 3.1.

A point θ^* is said to be a multidimensional median of the points $\{x_1,\ldots,x_m\}$ if for each component θ^{j*} we have $\theta^{j*} \geq x_i^j$ for at least one half of the m citizens and $\theta^{j*} \leq x_i^j$ for at least one half of the m citizens.

When m is an even number, we have (just as in the R^1 case) the possibility that more than one point θ^* will satisfy the definition. Thus, we let M^* denote the set of median points. This is illustrated for six points in Figure 3.1. Of course, M^* consists of just one point θ^* when m is an odd

number. (Insert Figure 3.1)

Now consider a generalization of the one dimensional issue space case to a multidimensional issue space where the points x_i are collinear (i.e., lie along some straight line). Such a situation is illustrated in Figure 3.2 where x_1, x_2, and x_3 lie along the line L. (Insert Figure 3.2). Of course, in a one dimensional issue space the positions are always collinear.

Given that the points $\{x_1,\ldots,x_n\}$ are collinear in R^n along some line L we now ask the following question:

(3.2) Under what conditions can we reduce the search for an equilibrium point to points on the line L?

Such a question is important since if such a reduction can be made then we will essentially be in the case considered by Theorem 1.1. In particular, then, an equilibrium position would exist at the median position(s) along line L (i.e., the point(s) $M^* \subset L$). This would be a direct multi-dimensional generalization of Theorem 1.1 to location at medians.

Unfortuantely, such a reduction can not always be made. If, for example, citizen 1 measures distance via the ℓ_1 norm, citizen 3 uses the ℓ_∞ norm, and citizen 2 uses a "generalized" Euclidian norm. (e.g., where the indifference contours are given in Figure 3.2), then no position θ_2 on L will ever beat θ_1 in a majority election. In particular, only citizen 1 could prefer positions θ_2 on L to the left of point A over the position θ_1. Similarly, only citizen 3 could prefer position θ_2 on L to the right of point B over the position θ_1. Finally, only citizen 2 could prefer position θ_2 between points A and B to the position θ_1. In short, no θ_2 along L could ever hope to beat the position θ_1 in an election.

There is, however, one important case when such a reduction can be made. Before stating this case, we first give a result upon which it depends.

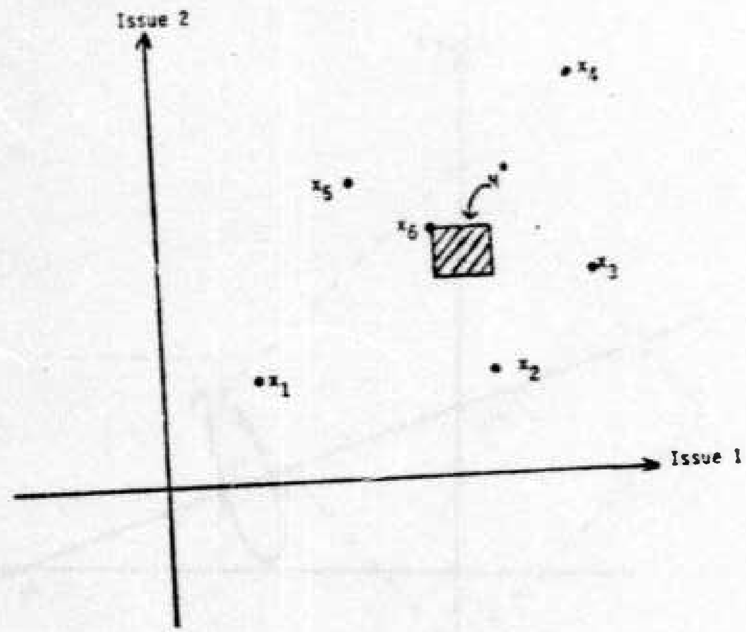


Figure 3.1

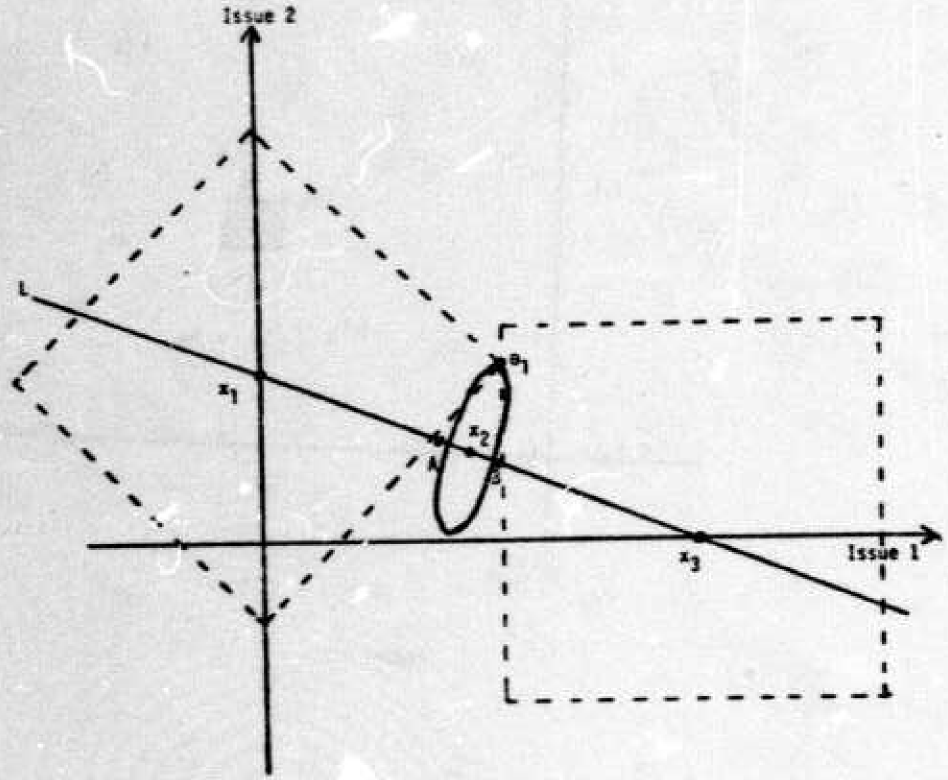


Figure 3.2

<u>Lemma</u>. Let $||\cdot||$ be any norm. If the points $\{x_1,\ldots,x_m\}$ are collinear in R^n along a line L then for every $\theta_1 \notin L$ there exists some $\theta_2 \in L$ such that

$$(3.3) \qquad ||\theta_2 - x_i|| \leq ||\theta_1 - x_i|| \text{ for } i=1,\ldots,m$$

The above Lemma follows from Theorems 2 and 3 in [25] (e.g., condition (3.3) is what is called dominance in [25] as distinct from the use of this word in spatial theory).

Note that the above Lemma says that <u>for every position θ_1 not on L there exists at least one position θ_2 on L such that each citizen i is either indifferent between θ_1 and θ_2 or the citizen strictly prefers θ_2 to θ_1</u>. Thus, positions not on L can be disregarded so that we get the following result.

<u>Theorem 3.1</u>. Suppose that the locations of citizens positions are collinear along some line L in R^n. Also suppose that each citizen measures distance in R^n via the same norm. Then a median θ^* of the positions $\{x_1,\ldots,x_m\}$ along L (i.e., $\theta^* \in M^* \subset L$) is a plurality equilibrium point. Furthermore, if m is an odd number then the median θ^* is a unique plurality equilibrium point.

The proof of the above theorem is given in the Appendix. Unlike Theorem 1.1 note that Theorem 3.1 only guarantees that the "median" is a plurality equilibrium point in contrast to a majority equilibrium point. Figure 3.3 illustrates a case where θ^* is not a majority equilibrium point (e.g., citizens 1 and 2 are indifferent between θ^* and θ). Under certain norms (e.g., the Euclidian norm) the result in Theorem 3.1 may be strengthened to assert the existence of a majority equilibrium point. We will not pursue this here. (insert Figure 3.3).

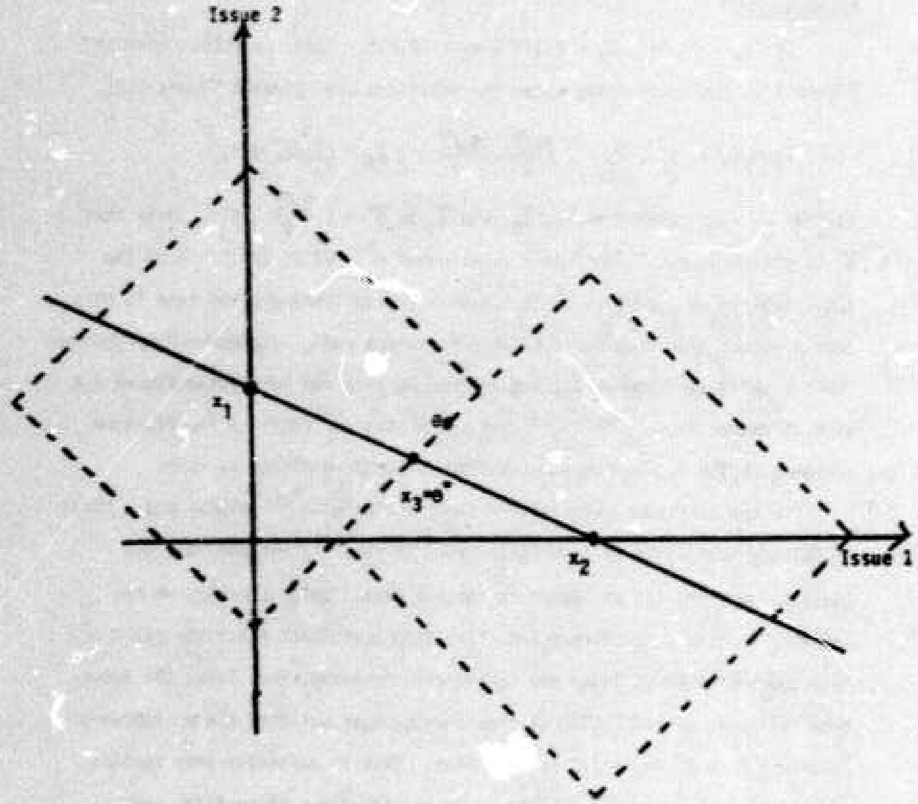


Figure 3.3

25

In the above discussion we have just shown that the "median" is an equilibrium point in a multidimensional issue space when the positions of the citizens are collinear and when they all measure distance via the same norm. We now proceed to again generalize the median equilibrium result from a one dimensional issue space to a multidimensional issue space situation. More specifically, we will generalize the result to a two dimensional issue space where all citizens measure distance via the ℓ_1 norm. No collinearity assumption or even symmetry assumptions about the distribution $f(x)$ of the citizens' positions will be made. In particular, we state this result as follows.

<u>Theorem 3.2</u>. If each of the m citizens measures distance via the ℓ_1 norm in a two dimensional issue space R^2, then the multidimensional median θ^* of the citizens' positions is a plurality equilibrium point. Furthermore, if m is odd, then θ^* is a unique plurality equilibrium point.

Again, the proof of this theorem is given in the Appendix. Note that Figure 3.3 illustrates a case where θ^* is not a majority equilibrium point.

The above Theorem is interesting and important since it is a direct multidimensional generalization of the well known one dimensional result of location at a median. It is, however, also interesting that the result in Theorem 3.2 cannot be directly extended to R^n for $n \geq 3$. We illustrate this with an example.

<u>Example 3.1</u>

In the three dimensional issue space R^3 suppose that $x_1=(1,1,0)'$, $x_2=(1,0,1)'$, $x_3=(0,1,1)'$, $x_4=(-1,-1,-1)'$, and $x_5=(-1,-2,-3)'$. Note that $\theta^*=(0,0,0)'$ is the multidimensional median. Consider another position

$\bar{\theta} = (1,1,1)'$. Then, using the ℓ_1 norm $||\cdot||^{(1)}$, we have

$$||x_1-\theta^*||^{(1)} = |1-0| + |1-0| + |0-0| = 2$$

$$||x_2-\theta^*||^{(1)} = |1-0| + |0-0| + |1-0| = 2$$

$$||x_3-\theta^*||^{(1)} = |0-0| + |1-0| + |1-0| = 2$$

$$||x_1-\bar{\theta}||^{(1)} = |1-1| + |1-1| + |0-1| = 1$$

$$||x_2-\bar{\theta}||^{(1)} = |1-1| + |0-1| + |1-1| = 1$$

$$||x_3-\bar{\theta}||^{(1)} = |0-1| + |1-1| + |1-1| = 1.$$

From this we note that

$$||x_i-\theta^*||^{(1)} > ||x_i-\bar{\theta}||^{(1)} \text{ for } i=1,2,3.$$

Thus $q(\bar{\theta}) > p(\bar{\theta})$ and we conclude that θ^* is not an equilibrium point. In other words, $\bar{\theta}$ would beat θ^* in a majority election.

We now conclude this section with an examination of the equilibrium point existence question when the norm in (3.1) for all persons is the ℓ_∞ norm. Before doing this, however, we first make the following definition.

<u>Definition 3.2</u>.

Let $\{x_1,\ldots,x_m\}$ and θ^* be points in a two dimensional issue space R^2. Further, let $\{\bar{x}_1,\ldots,\bar{x}_m\}$ and $\bar{\theta}^*$ be the new coordinates of the points $\{x_1,\ldots,x_m\}$ and θ^* under a 45 degree rotation of the coordinate axes. Then θ^* is said to be a <u>rotated two dimensional median</u> of $\{x_1,\ldots,x_m\}$ if $\bar{\theta}^*$ is the multidimensional median of $\{\bar{x}_1,\ldots,\bar{x}_m\}$.

Although we will illustrate this definition in Example 3.2, we first state the following result.

<u>Theorem 3.3</u>. If each of the m citizens measures distance via the ℓ_∞ norm in a two dimensional issue space R^2, the rotated two dimensional median of $\{x_1,\ldots,x_m\}$ is a plurality equilibrium point. Furthermore, if m is odd then this is a unique plurality equilibrium point.

The proof of this theorem is a direct result of Theorem 2.2 and Theorem 3.2. We now illustrate the theorem and the definition via an example.

<u>Example 3.2</u>

Let $x_1 = (1,1)'$, $x_2 = (0,3)'$, $x_3 = (2,2)'$. Then, as illustrated in Figure 3.4, the coordinates under the rotations are (insert Figure 3.4)

$$\bar{x}_1 = (\sqrt{2},\ 0)',\ \bar{x}_2 = \left(\frac{3\sqrt{2}}{2},\ \frac{3\sqrt{2}}{2}\right)',\ \bar{x}_3 = (2\sqrt{2},\ 0)'.$$

The median with respect to $\bar{x}_1$, $\bar{x}_2$, and $\bar{x}_3$ is $\bar{\theta}^* = \left(\frac{3\sqrt{2}}{2},\ 0\right)'$. Note that $\bar{\theta}^*$ is the point resulting from a rotation of $\theta^* = (3/2,\ 3/2)'$. From the above theorem we know that θ^* is a plurality equilibrium point (and in this case a unique plurality equilibrium point since m=3). The equivalence between the results in Theorems 3.2 and 3.3 can be observed by viewing Figure 3.4 at a 45 degree angle. In particular, note that the box-like indifference contours of the ℓ_∞ norm become the diamond contours of the ℓ_1 norm.

We now make some observations about the results in Theorem 3.3. First, we believe that it is an important result in that it characterizes the equilibrium point for an important special case. Unfortunately, we are not able to give much "direct intuitive interpretation" about the point θ^*. This appears to be at least one case where the mathematics leads the intuition (at least to us). Also it should be pointed out that the extension of Theorem 3.3 to R^n for $n \geq 3$ is not clear. This is partially true because our definition of a rotated median only considers two dimensions, and since the relationship between the ℓ_1 and the ℓ_∞ norms breaks down for R^3. This is further discussed in Section 2.

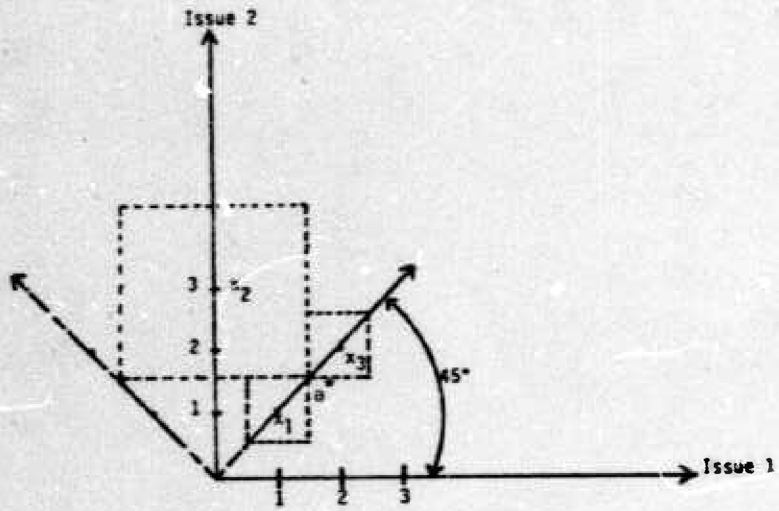


Figure 3.4

4. Conclusions

In this section, we will summarize and analyze our results. In particular, we will compare them to the optimal position that a benevolent dictator would select under a "similar" situation (the benevolent dictator problem has been extensively analyzed in [28]).

First we summarize our results of the paper. In Section 1 we define various kinds of equilibrium points (previously called dominant points) and review related results in the literature. In Section 2 we characterize a general class of indifference contours (e.g., see (2.1)) and point out that this class is equivalent to the class of functions called norms (see Theorem 2.1) Various examples are given including the "generalized" Euclidian norm used in previous multidimensional spatial theory (see example 2.1). Other examples include the ℓ_1 norm and the ℓ_∞ norm which have very important substantive interpretations in political science (see examples 2.2 and 2.3). We also point out the fact that the ℓ_1 and ℓ_∞ norms are equivalent in R^2 under a 45 degree coordinate rotation, but are not equivalent in R^n for $n \geq 3$ (see Theorem 2.2). In Section 3 we generalize the formulation of a loss function to allow for arbitrary norms and for the type of norm to depend upon the particular citizen (e.g., see (3.1)). In particular, the formulation in [6] becomes a special case. Then we consider the situation when the positions of the citizens are collinear (i.e., lie along some straight line L) in R^n. With respect to this situation we show that if all citizens use the same arbitrary norm to measure distance, then the median θ^* on line L will be an equilibrium point (see Theorem 3.1). If the citizens

do not use the same norm then this result is not true (e.g., see Figure 3.2). Then we consider a noncollinear case in R^2 where the citizens all measure distance via the ℓ_1 norm. In that case we show that the multidimensional median is an equilibrium point (see Theorem 3.2). Example 3.1 shows that this result is not true in R^n for $n \geq 3$. Similar to that case, we also consider a situation when again we are in a two dimensional issue space but where the citizens all measure distance via the ℓ_∞ norm. Here we establish that the rotated two dimensional median (see Definition 3.2) is an equilibrium point (see Theorem 3.3). In short, this paper presents both a generalization in the formulation and the results in the spatial theory of majority decision making.

We now compare our results of location at a median to where a benevolent dictator would locate in a "similar" situation. First we consider the case where the citizens positions lie along some line L in R^n and where the dictator desires to pick a location θ^* that minimizes the sum of distances to the citizens (e.g., if every citizen has the same loss function which is linear in distance, then the dictator is essentially minimizing total utility loss to society [28]). If each citizen uses the same norm then the median along L will be the optimal location of the dictator. If the citizens do not all have the same norm, then the optimal dictator position might not even be on the line L. These results are analagous to our results in this paper. If, on the other hand, the citizens do not have collinear positions but if they all use the ℓ_1 norm, then the dictator (with the same criterion as dis[illegible]nd above) will again select the median as his optimal position. Again, this is analagous to our result in Theorem 3.2 except that Theorem 3.2 only applies to a two dimensional issue space.

Similarly, an analogy exists for the ℓ_∞ case. We can summarize this comparison by concluding that a de[illegible]racy and dictatorship will both arrive at the same decision in similar situations where this decision is characterized by the median.

REFERENCES

1. Arrow, K., Social Choice and Individual Values, (2nd ed.), New Haven: Yale, 1963.

2. Attneave, F., "Dimensions of Similarity," American Journal of Psychology, Vol. 63, pp. 516-556, 1950.

3. Baumol, W. J., Economic Theory and Operations Analysis, Prentice-Hall, Englewood, Cliffs, N.J., 1965.

4. Black, D., The Theory of Committees and Elections, London: Cambridge, 1958.

5. Davis, O. A., DeGroot, M. H., and Hinich, M. J., "Social Preference Orderings and Majority Rule," Econometrica, Vol. 40, pp. 147-157, 1972.

6. Davis, O. A., Hinich, M. J., Ordeshook, P. C., "An Expository Development of a Mathematical Model of the Electoral Process," The American Political Science Review, Vol. LXIV, No. 2, pp. 426-448, June 1970.

7. Downs, A., "An Economic Theory of Political Action in a Democracy," Journal of Political Economy, Vol. 65, pp. 135-150, 1957.

8. Downs, A., An Economic Theory of Democracy, New York: Harper, 1957.

9. Fischer, W., and Micker, M. C., "More about Metrics of Subjective Spaces and Attention Distributions," Journal of Mathematical Psychology, Vol. 9, pp. 36-54, 1972.

10. Goldberg, R. R., Methods of Real Analysis, Blaisdell, Waltham, 1964.

11. Hotelling, H.,"Stability in Competition," Economic Journal, Vol. 39, pp. 41-57, 1929.

12. Householder, A. S., The Theory of Matrices in Numerical Analysis, Blaisdell, New York, 1965.

13. Hyman, R., and Well, A., "Judgements of Similarity and Spatial Models," Perception and Psychophysics, Vol. 2, pp. 233-248, 1967.

14. Kantorovich, L. Y., and Akilov, G. P., Functional Analysis in Normed Spaces, MacMillan: New York, 1964.

15. Kuhn, H. W., "On a Pair of Dual Nonlinear Programs," in Nonlinear Programming, (J. Abadie, ed), John Wiley, New York, 1967.

16. Luenberger, D. G., Optimization by Vector Space Methods, John Wiley, New York, 1969.

17. Mangasarian, O., Nonlinear Programming, McGraw-Hill, New York, 1969.

18. Ordeshook, P. C., "Extensions to a Model of the Electoral Process and Implications for the Theory of Responsible Parties," Midwest Journal of Political Science, Vol. XIV, No. 1, pp. 43-70, Feb. 1970.

19. Rockafellar, R. T., Convex Analysis, Princeton, 1970.

20. Shepard, R., "Attention and the Metric Structure of the Stimulus Space," Journal of Mathematical Psychology, Vol. 1, pp. 54-87, 1964.

21. Smithies, A., "Optimal Location in Spatial Competition," Journal of Political Economy, Vol. 49, pp. 423-429, 1941.

22. Stokes, D., "Spatial Models of Party Competition," American Political Science Review, Vol. 57, 1963.

23. Thorson, S. J., and Wendell, R. E., "Spatial Analysis of Electoral Behavior," (in preparation).

24. Tullock, G., Towards A Mathematics of Politics, Ann Arbor, Michigan, 1968.

25. Wendell, R. E., and Hurter, A. P., "Location Theory, Dominance, and Convexity," Operations Research (to appear).

26. Wendell, R. E., and Hurter, A. P., "Optimal Location on a Network," Transportation Science, Vol. 6, November 1972.

27. Wendell, R. E., and Petersen, E. L., "Duality in Generalized Location Problems," Location Theory Session, Joint National Meeting of ORSA, TIMS, and AIIE, November, 1972.

28. Wendell, R. E., and Thorson, S. J., "Generalized Spatial Analysis of a Dictatorship," (submitted for publication).

29. Wendell, R. E., and Thorson, S. J., "Location Theory and the Social Sciences: Optimal Decision for a Committee or a Country," Location Theory Session, 43rd National Meeting of the Operations Research Society of America, May 1973.

APPENDIX

Proof of Theorem 3.1

Suppose that θ^* is not a plurality equilibrium point. Then from Definition 1.1 we assert the existence of some $\theta \in R^n$ such that $q(\theta) > p(\theta)$ (i.e., the number of citizens strictly preferring θ over θ^* is greater than the number strictly preferring θ^* over θ).

Now if $\theta \notin L$ then by the Lemma we assert the existence of $\bar{\theta} \in L$ such that $||\bar{\theta}-x_i|| \leq ||\theta-x_i||$ for $i=1,\ldots,m$. If $\theta \in L$, let $\bar{\theta} = \theta$. Thus we have a position $\bar{\theta} \in L$ such that

$$||\bar{\theta}-x_i|| \leq ||\theta-x_i|| \quad \text{for } i=1,\ldots,m.$$

Consider two cases:

(i) $\bar{\theta} = \theta^*$;

(ii) $\bar{\theta} \neq \theta^*$.

In case (i) all citizens either strictly prefer $\bar{\theta} = \theta^*$ to θ or they are indifferent. This, however, contradicts our assertion that $q(\theta) > p(\theta)$. Thus case (i) is impossible.

We now consider case (ii). Since $\bar{\theta} \in L$ and since $\bar{\theta} \neq \theta^*$, the properties of a norm imply that at least one half of the citizens would strictly prefer θ^* to $\bar{\theta}$ (i.e., those citizens on L who are either located at θ^* or are on the opposite side of θ^* from $\bar{\theta}$). In particular, for these citizens (who compose at least one half of all the citizens m) we have

$$||\theta^*-x_i|| < ||\bar{\theta}-x_i|| .$$

For these same citizens we have

$$||\theta^*-x_i|| < ||\theta-x_i|| .$$

Thus, for these same citizens, we have from (3.1) that

$$L_i(\theta^*) < L_i(\theta) .$$

And again, since at least one half of the citizens have this preference, we conclude that $p(\theta) \geq q(\theta)$. This is a contradiction to $q(\theta) > p(\theta)$ and we conclude that case (ii) is also impossible. Thus, by contradiction we have shown that a median θ^* must be a plurality equilibrium point.

To prove the uniqueness when m is odd we again consider two cases:

(i) $\bar{\theta} = \theta^*$;

(ii) $\bar{\theta} \neq \theta^*$.

In case (ii) we can use the same argument as before to argue that more than one half of the citizens will prefer θ^* to θ . Thus, in this case, we have $p(\theta) \geq q(\theta)$ which would contradict $q(\theta) \leq p(\theta)$.

In case (i) we have shown that the citizen located at the median will strictly prefer θ^* to θ while all the other citizens will either strictly prefer θ^* to θ or they will be indifferent. Thus, again, we have $p(\theta) \geq q(\theta)$ which would contradict $q(\theta) \leq p(\theta)$. Hence, we have proved the theorem.

Proof of Theorem 3.2

We exploit the fact that we are in R^2 by giving a simple geometric proof. In particular, we illustrate a typical situation in Figure A.1, where, for the six points $\{x_1,x_2,x_3,x_4,x_5,x_6\}$, θ^* is a point in M^*. Note that we have divided the R^2 space into "pie-shaped" regions via the lines AA', BB', CC', and DD'. (Insert Figure A.1).

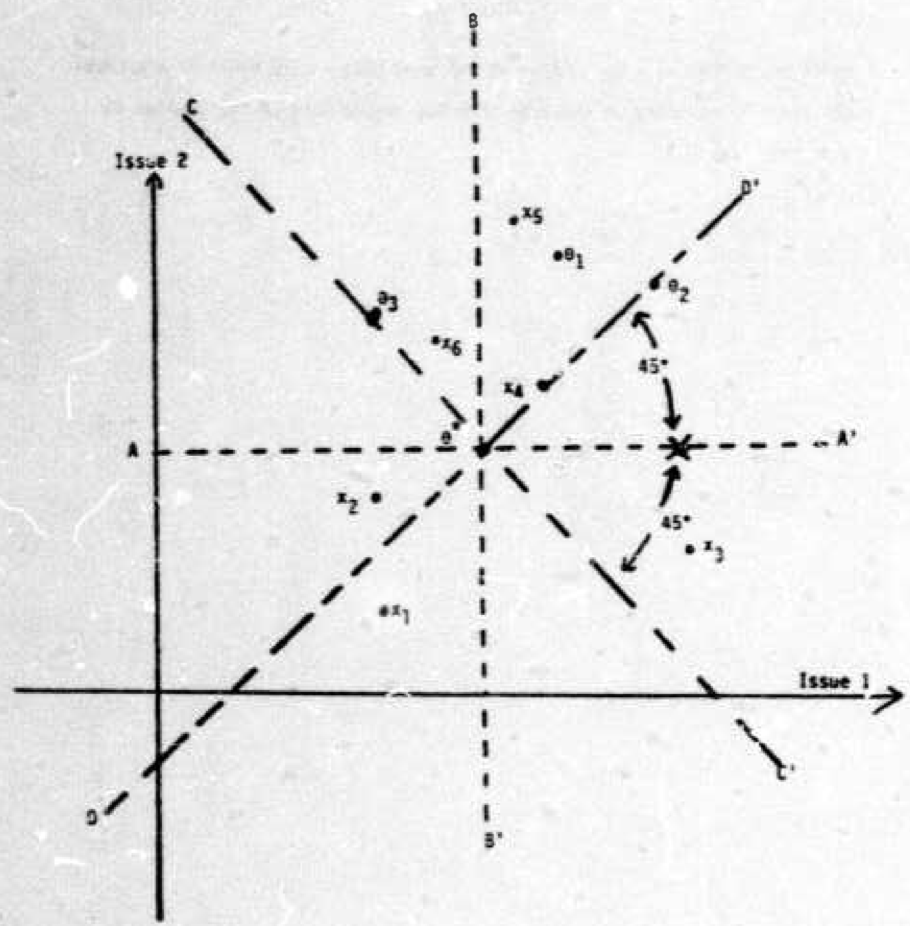


Figure A.1

Now suppose that θ^* is not a plurality equilibrium point. Then there exists some $\theta \in R^2$ such that there are more citizens who strictly prefer θ than there are citizens who strictly prefer θ^* (i.e., $q(\theta) > p(\theta)$). Clearly θ will be in one of the four "pie-shaped" regions $C\theta^*D'$, $C'\theta^*D'$, $C'\theta^*D$, or $C\theta^*D$. First let's suppose that it is in the region $C\theta^*D'$. In that case there are only three possibilities:

(i) θ lies interior to the region $C\theta^*D'$ (as illustrated by the point θ_1);

(ii) θ lies on the half line θ^*D' (as illustrated by the point θ_2);

(iii) θ lies on the half line θ^*C (as illustrated by the point θ_3).

First we consider case (i). Since θ^* is a median position with respect to issue 2, at least one half of the citizens will have positions on or below the line AA'. By considering the indifference contours of each of these citizens (as illustrated in Figure 2.3), it is clear that each of these citizens would strictly prefer θ^* to θ. Therefore, in this case, we would have $p(\theta) \geq q(\theta)$. Since this contradicts $q(\theta) > p(\theta)$, case (i) is impossible.

We now consider case (ii). Define:

$\gamma_1 \equiv$ the number of citizens in the region $A\theta^*B'$;

$\gamma_2 \equiv$ the number of citizens in the interior of the region $A'\theta^*B'$ plus the number of citizens on the half line θ^*A' (with the exception of the point θ^*).

$\gamma_3 \equiv$ the number of citizens in the interior of the region $A\theta^*B$ plus the number of citizens on the half line θ^*B (with the exception of the point θ^*);

$\gamma_4 \equiv$ the number of citizens in the interior of the region $A'\theta^*B$. Note that the above classification divides R^2 into four non-overlapping areas. Furthermore, since θ^* is a median we have that

$$\gamma_1 + \gamma_2 \geq \gamma_3 + \gamma_4$$

and

$$\gamma_1 + \gamma_3 \geq \gamma_2 + \gamma_4 \ .$$

These inequalities imply that

$$(\gamma_1 + \gamma_2) - (\gamma_2 + \gamma_4) \geq (\gamma_3 + \gamma_4) - (\gamma_1 + \gamma_3) \ .$$

This reduces to the inequality $\gamma_1 \geq \gamma_4$.

We again appeal to the shape of the t_1 indifference contours to assert that for θ on the half line θ^*D': the γ_1 citizens will strictly prefer θ^* over θ; the γ_2 and γ_3 citizens will either be indifferent between θ^* and θ or they will strictly prefer θ^* over θ; and the γ_4 citizens will strictly prefer θ over θ^*. But since $\gamma_1 \geq \gamma_4$ we conclude that the number of citizens strictly preferring θ^* over θ is greater than the number strictly preferring θ over θ^*. Thus $p(\theta) \geq q(\theta)$ which contradicts $p(\theta) > p(\theta)$ and we conclude that case (ii) is impossible. By symmetry we assert that case (iii) is impossible. Also by symmetry we assert that the same arguments can be made for any of the other regions $C'\theta^*D'$, $C'\theta^*D$, or $C\theta^*D$. Hence no such θ can exist and the first part of the theorem is proved by contradiction.

We now prove the assertion in the second part of the theorem that θ^* is the unique plurality equilibrium point when m is odd. If not true, then there exists some θ such that $q(\theta) \geq p(\theta)$. Following the proof to the first part of the theorem, we first consider case (i). Since m is odd, we can assert that over one half of the citizens lie on or below line AA'. Thus

we get that $p(\theta) > q(\theta)$ which is a contradiction. If case (ii) applies one can see that

$$\gamma_1 + \gamma_2 > \gamma_3 + \gamma_4$$

and

$$\gamma_1 + \gamma_3 > \gamma_2 + \gamma_4$$

which imply that $\gamma_1 > \gamma_4$. Again we get that $p(\theta) > q(\theta)$ which is a contradiction. By symmetry we conclude that the second part of the theorem is also true.

A Mathematical Study
of
Decisions in a Dictatorship

R.E. Wendell
and
S.J. Thorson*

March 1973
Project Research Paper No. 9

Presented at the George Washington University Nonlinear Programming Symposium, March, 1973.

Prepared in connection with research supported by the Advanced Research Projects Agency, ARPA Order No. 2345-3D20, Contract No. DAHC 15 73 C 0197, RF 3527-A1.

*Department of Industrial and Systems Engineering and the Project for Theoretical Politics, respectively, Ohio State University.

INTRODUCTION

Since the work of Hotelling [14] a growing number of political theorists have been explicitly employing "spatial" techniques to investigate various aspects of electoral behavior. Perhaps the work in this area which is best known to political scientists is that of Downs [8]. More recently there has been considerable theoretical work done expanding the Downs approach. Much of this research has been made possible by exploiting the increased deductive power of mathematics. One of the greatest virtues of expressing political theories in a mathematical language is the relative ease with which previous results may be generalized. The advantage of generality in empirical theory is, of course, that the more general the statement the less it assumes to be true of reality. As an example, the analysis done by Downs assumes (among other things) that every voter's "most preferred position" can be located somewhere in a one dimensional issue space. As Stokes [28] has pointed out, there is strong empirical evidence that no such single dimension exists. A way around this objection is then to assume that each citizen's "most preferred position" can be located somewhere in an "n" dimensional space. Theory statements derived under this assumption are no longer dependent upon the (empirical) existence of a one dimensional issue space. In summary, therefore, the more general the assumptions, the less must be true in any reality for the theory to be true of that reality.

The major concern of this paper will be to generalize a number of the assumptions and results of Davis, Hinich and Ordeshook [5] . The nature of these assumptions (as well as our generalizations) will be explicated in succeeding sections of this paper. The specific problem which will be focused upon will be that of where in some n-dimensional issue space a benevolent dictator ought to locate if he (she) wishes to maximize some well defined objectives (such as minimize citizens total utility loss or minimize maximum citizen utility loss). In other papers [34] [29] [35], this analysis is extended to candidate positions under majority rule.

The benevolent dictator problem is especially tractable since it is formally very similar to problems arising in Operations Research under the heading of "plant location problems." This problem deals with the question of where in some space (generally two-dimensional) a plant ought be located if it is to minimize the cost of shipping inputs from various points in that space to the plant. Kuhn [19] sets up this problem as:

$$\underset{X}{\mathrm{Min}} \sum_{i=1}^{m} w^i \, || X - d_i ||$$

where $X \equiv$ vector variable in the space denoting the location of the plant

$w^i \equiv$ cost per unit distance of shipping a (known) quantity of input i from d_i

$|| X - d_i || \equiv$ the (generally Euclidean) distance from X to d_i.

As will be shown, this is very much analagous to the dictator problem where X would be the dictator's location, w^i the i_{th} citizen's loss function and $|| \cdot ||$ the measure of distance of the i_{th} person from the dictator's position.

This formal similarity is very nice as it allows us to directly reinterpret much of "plant location theory" directly into political science terms*. An important side benefit of this is that this reinterpretation

*In model-theoretic terms, a model for plant location theory can be found in political science.

motivates new theorems which can be added to the corpus of both "plant location theory" and "political theory." The wedding of "plant location theory" with "spatial analysis" is interesting both in terms of the advances it permits in political theory and in terms of new mathematical results.

1. Spatial Theory and the Dictator Problem

In recent years various articles (see, for example [5], [24]) have formulated and analyzed political processes using a spatial theory approach. We will not give the background or assumptions of this approach here (see [5] for a good introduction), but instead we will simply review the notation and formulations that have been established elsewhere [5], [24].

Consider a situation in which there are n issues. Then following [5] we define*:

$x_i \equiv (x_i^1, x_i^2, \ldots, x_i^n)' \equiv$ the vector that characterizes the position of citizen i for each of the m citizens ($i = 1, \ldots, m$) on all n issues, $x_i \in R^n$, and R^n will be called the issue space (e.g., R^n is the usual space of real n-tuples);

$\theta \equiv (\theta^1, \theta^2, \cdots, \theta^n)' \equiv$ the vector of positions advocated by the dictator**, $\theta \subset R^n$;

$L_i(\theta) \equiv$ the loss citizen i sustains from the dictator's position θ;

$A \equiv$ a positive definite symmetric nxn matrix such that $(x_i - \theta)' A (x_i - \theta)$ generates indifference

---

*The notation "'" denotes the transpose of a vector. Unlike [5] we use superscripts to denote components of a vector. The distinction between superscripts and exponents will be clear from the context.

**In a democracy analysis this is commonly used to denote the position of a candidate.

contours* for the loss function of citizen i about

his location x_i;

$\phi(\cdot) \equiv$ a monotonically increasing function of its argument

such that $L_i(\theta) = \phi((x_i - \theta)' A (x_i - \theta))$.

With respect to this notation Davis, Hinich, and Ordeshook (see page 441 of [5]) consider the problem of "an omniscient and beneficent dictator faced with the task of selecting the 'best' policies** for his country." In particular, the dictator may simply wish to "minimize the total utility loss of the society." In this case with respect to the above notation his problem becomes

$$(1.1)\ \underset{\theta}{\mathrm{Min}} \sum_{i=1}^{m} \phi((x_i - \theta)' A (x_i - \theta)).$$

Note that the above formulation implicitly assumes that such a dictator weights each citizen identically. Following [5], we now generalize this to the possibility of unequal weights for the citizens. First we define:

$f(x) \equiv$ "the electorate's preference density" that gives the distribution of the citizens x_i in the issue space;

$w(x) \equiv$ a "weighting function" that assigns a positive weight $w(x_i)$ to each citizen i.

Now we can state the more general dictator problem:

$$(1.2)\ \underset{\theta}{\mathrm{Min}} \sum_{i=1}^{m} w(x_i)\, \phi((x_i - \theta)' A (x_i - \theta)).$$

Note that if all the weights $w(x_i)$ are equal, then problem (1.2) reduces to problem (1.1).

---

*See [34] or any good economics text for a definition of indifference contours.

**As we shall see, "best" is a very ambiguous criterion by which to analyze policies.

For simplicity, we will choose the mean of "the electorate's preference density" $f(x)$ as the origin of our coordinate system. Then, following [5], we make the following assumptions:

(1.3) (i) $f(x)$ is symmetric about the origin (e.g. about its mean);

(ii) $w(x)$ is symmetric about the origin (e.g. about the mean of $f(x)$).

Assumption (i) simply implies that for every citizen i at a position x_i there exists a citizen k at a position $-x_i$. Assumption (ii) simply means that $w(x) = w(-x)$.

It is interesting to note that Davis, Hinich, and Ordeshook [5] distinguish two general forms of the weighting function $w(x)$. "First, the beneficient dictator might assign more importance to those in the 'middle' than to those who held extreme positions, and in this instance we say that $w(x)$ is unimodal. Second, the dictator might weight 'liberals' and 'conservatives' more heavily than 'moderates' and in this instance $w(x)$ is termed not unimodal." If one carries this weighting of "extremists" to the extreme (e.g. to the point where the dictator is only concerned about them) then we essentially get the class of problems which we consider in section 4. Otherwise, the problem will be a special case of the type that we consider in section 3.

With respect to problem (1.2), we can choose the eigenvectors of A as a basis for R^n with an associated scale change on each of the axes according to the square root of the respective eigenvalue* to get the following

---

*See pages 432 to 434 of [5] and especially footnote 18 on page 434 for more discussion on this point.

problem which is equivalent to (1.2):

$$(1.4) \quad \min_{\theta} \sum_{i=1}^{m} w(x_i)\,\phi\,((x_i - \theta)'\,(x_i - \theta)) \quad .$$

Differentiating (1.4) with respect to θ^k we get the first order necessary conditions*:

$$\sum_{i=1}^{m} w(x_i)\,[\dot{\phi}((x_i - \theta)'\,(x_i - \theta))]\,[(\theta^k - x_i^k)] = 0$$

for $k = 1, \ldots, n$. For $\theta = 0$ this reduces to

$$(1.5) \quad \sum_{i=1}^{m} w(x_i)\,[\dot{\phi}\,(x_i'\,x_i)]\,[x_i^k] = 0 \text{ for } k = 1, \ldots, n.$$

By the assumptions in (1.3) the conditions (1.5) are certainly true. Thus, the mean of $f(x)$ is certainly a possible candidate as the optimal location for the dictator (e.g. it is a stationary point). To sh w that it is indeed the optimal location further analysis is required.

In the case where the loss functions are marginally increasing one can argue via convexity that such a point will always be the optimal dictator location (e.g. the global solution). Otherwise, this cannot be guaranteed unless we have even more special situations. In particular, Davis, Hinich, and Ordeshook [5] claim that even when loss functions may be marginally increasing and marginally decreasing the optimal location is still at the mean if we further assume that both $f(x)$ and $w(x)$ are unimodal**. Although they don't justify this claim, it probably results from some argument involving strict quasiconvexity.

---

*$\dot{\phi}$ ( ) means the derivative of ϕ.

**In the discrete case where the number of citizens is finite, the definition of unimodality of $f(x)$ given on page 436 of [5] is not clear. In particular, if each citizen's location is distinct, then each x_i may be viewed as a mode of $f(x)$.

DICTATOR'S PREFERENCE

	Loss Functions Marginally Increasing Only		Loss Functions Marginally Increasing and Marginally Decreasing	
f(x)	w(x) Unimodal	Otherwise	w(x) Unimodal	Otherwise
Symmetric Unimodal	Mean	Mean	Mean	No General Solution
Symmetric Bimodal	Mean	Mean	No General Solution	No General Solution

TABLE 1.1

Finally, we summarize the results of the Hinich, Davis, Ordeshook analysis of the dictator problem in Table 1.1. Based on this table they conclude:

PLACE TABLE 1.1 ABOUT HERE

"The point here, however, is that in a variety of ethical assumptions arbitrarity assigned, the mean appears to be a desirable point. Accordingly, contrary to the responsible parties doctrine, forces which cause both party platforms to converge toward the mean, rather than recognizing differences in opinion, are not necessarily 'bad' and, in the majority of the above cases, are positively 'good' if one is willing to accept the assumptions."

2. Metrics and Norms

A central assumption of the "spatial approach" is that each citizen's "loss" from a particular position of the dictator is dependent upon the (citizen's) perceived dissimilarity between the dictator's spatial location and the location of the citizen. This perceived dissimilarity may be treated as having the properties of a distance metric.

More formally, the problem is to measure the distance between any two points ξ_1 and ξ_2 in R^n. In general, the problem is to define a function $\rho(\xi_1, \xi_2)$ from pairs of points ξ_1, ξ_2 into R^1 such that the resulting scalar measures the distance between the points ξ_1 and ξ_2. If such a distance function satisfies the following properties, then it is called a metric (see [13], or [17] for further discussion).

(2.1) (i) $\rho(\xi_1, \xi_2) \geq 0$ for all $\xi_1, \xi_2 \in R^n$ (e.g. distance is always non-negative);

(i) $\rho(\xi_1, \xi_2) = 0$ iff $\xi_1 = \xi_2$ (e.g. distance between two points is zero iff the two points are identical);

(iii) $\rho(\xi_1, \xi_2) = \rho(\xi_2, \xi_1)$ (e.g. the distance from one point to a second is equal to the distance from the second to the first);

(iv) $\rho(\xi_1, \xi_2) \leq \rho(\xi_1, \xi_3) + \rho(\xi_3, \xi_2)$ (e.g. the distance from one point to another is alw[illegible] less than or equal to the sum of the distance from these points to a third point).

Property (iii) is often called the symmetry property while property (iv) is the triangle inequality. The metric is a general distance measure which

includes many more specific distance measures as special cases.

The general properties of a metric are satisfied by many distance functions. Perhaps the most familiar of these is the Euclidean distance function. Indeed all the work done by Davis, Hinich, and Ordeshook assumes the Euclidean metric for all citizens. However empirical work done by perceptual psychologists [2], [10], [16], [26] suggests very strongly that other metrics may be appropriate for best ordering wide ranges of data.

If this be the case, several classes of problems become important. First, what of the cases where all citizens have the same metric but that metric is of some other form than the Euclidean. Second, and more generally, what if the distance measure "used" by each citizen satisfies the properties of a metric, but no restrictions are placed as to what specific metric any particular citizen employs. In order to investigate these problems it is first necessary to provide a general discussion of distance measures and define several potentially interesting non-Euclidean measures.

<u>Example 2.1</u>

Define

$$\rho(\xi_1, \xi_2) = \begin{cases} 1 \text{ if } \xi_1 \neq \xi_2 \\ 0 \text{ if } \xi_1 = \xi_2 \end{cases}$$

Since properties (i), (ii), (iii), and (iv) are true, $\rho(\xi_1, \xi_2)$ is clearly a metric. A citizen x_i having such a metric in an issue space is one who can distinguish whether the dictator agrees with him (e.g. $\theta = x_i$) or disagrees with him (e.g. $\theta \neq x_i$) but can make no distinctions as to the <u>extent</u> of disagreement.

Unlike a metric which maps $R^n \times R^n$ into R^1*, we now define a norm which maps R^n into R^1 (see [17] or [22] for a further discussion). In particular, a norm is a function $||\cdot||$ with the following properties:

(2.2) (i) $||\xi|| \geq$ for all $\xi \in R^n$;

(ii) $||\xi|| = 0$ iff $\xi = 0$;

(iii) $||\xi|| = ||-\xi||$;

(iv) $||\bar{\xi}_1 + \bar{\xi}_2|| \leq ||\bar{\xi}_1|| + ||\bar{\xi}_2||$ for $\bar{\xi}_1, \bar{\xi}_2 \in R^n$** ;

(v) $||\alpha\xi|| = |\alpha|\,||\xi||$ for any scalar α .

With the exception of property (v), the properties of a metric are similar to those of a norm. In particular, given a norm $||\cdot||$ we can define a metric

$$\rho(\xi_1, \xi_2) \equiv ||\xi_1 - \xi_2||$$

and verify the corresponding metric properties by letting $\xi \equiv \xi_1 - \xi_2$, $\bar{\xi}_1 \equiv \xi_1 - \xi_3$, and $\bar{\xi}_2 \equiv \xi_3 - \xi_2$. <u>Thus, we can think of a norm as a special case of a metric</u>. On the other hand, if the metric $\rho(\cdot,\cdot)$ satisfies the additional properties (see page 50 of [17]).

(2.3) (v) $\rho(\xi_1 + \xi_3, \xi_2 + \xi_3) = \rho(\xi_1, \xi_2)$

(vi) $\rho(\alpha\xi_1, \alpha\xi_2) = |\alpha|\,\rho(\xi_1, \xi_2)$ for any scalar α ,

then the metric $\rho(\cdot,\cdot)$ can be used to define a norm

$||\xi|| \equiv \rho(\xi_1, 0)$

*$R^n \times R^n$ is the Cartesian product of R^n with R^n

**$\bar{\xi}_1$ and $\bar{\xi}_2$ are arbitrary vectors in R^n and this notation is used to eliminate confusion with the definition of a metric in subsequent discussion.

There are many different types of norms of which we will now give some examples.

<u>Example 2.2</u>: City Block Norm

Consider a norm defined as

$$||\xi||^{(1)} \equiv \sum_{j=1}^{n} | \xi^j | \quad \text{where } \xi \in R^n$$

(e.g. the superscript (1) is used to denote this type of norm).

Such a norm is often called the city block norm, the Manhattan norm, or the ℓ_1 norm. The reason for the former names is that in various urban areas (e.g. Manhattan) the city streets are in the north-south and east-west directions. Given a north-south and east-west coordinate system, a distance vector ξ has a length given by the sum of absolute values of the coordinates. For example, see Figure 2.1. The reason for it being called the ℓ_1 norm will become clear in Example 5.

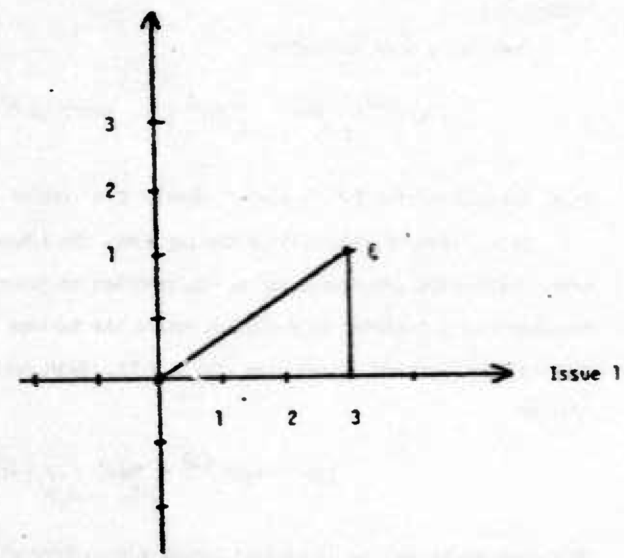
Besides the above interpretation, the ℓ_1 norm has an interesting interpretation in distance perceptions in an issue space. Consider a citizen's position at a point x_i and a dictator's position at the point θ. Then

$$|| \theta - x_i||^{(1)} = \sum_{j=1}^{n} |\theta^j - x_i^j |$$

and the citizen views the distance from him to the dictator as the sum of the distances that their views vary on each issue.

PLACE FIGURE 2.1 ABOUT HERE

Since the empirical work of Attneave [2], the city block norm has been of some interest to psychologists in analyzing perceptual data. Indeed the argument has been made [2] that the city block norm rather than the



$$|| \xi ||^{(1)} = |3| + |2| = 3 + 2 = 5$$
$$|| \xi ||^{(2)} = [(3)^2 + (2)^2]^{1/2} = [13]^{1/2}$$
$$|| \xi ||^{(\infty)} = \text{Max} \{ |3|, |2| \} = 3$$

Figure 2.1

Euclidean should be considered as fundamental for ordering perceptual data, since subjects seemed to judge dissimilarities in geometric stimuli by independently judging differences in components (dimensions). Further, the city block norm has nice additive properties not possessed by the Euclidean norm. Indifference contours of this type of individual are given in Figure 2.2. Note the diamond shape of these contours.

<u>Example 2.3</u>

Consider a norm defined as

$$||\xi||^{(\infty)} \equiv \underset{j=1, \ldots, n}{\text{Max}} \{|\xi^j|\} \quad \text{where } \xi \varepsilon R^n$$

(e.g. the superscript (∞) is used to denote this type of norm).

Such a norm is often called the sup norm, the Tchebvcheff, or the L_∞ norm. Unlike the previous norm, the L_∞ norm has an interpretion that the distance from a dictator to a citizen equals the maximum of the differences in positions over all issues (see Figure 2.1). Mathematically, we write this as

$$||\theta - x_i||^{(\infty)} = \underset{j=1, \ldots, n}{\text{Max}} \{|\theta^j - x_i^j|\} .$$

This norm might well be of special interest in political science. In particular, a citizen who measures distance under such a norm would ignore a dictator's position on all issues but the one which achieved maximum disparity (e.g. Vietnam).

PLACE FIGURE 2.2 ABOUT HERE

As shown in Figure 2.2 the indifference contours for this type of norm are box-like. Since a rotation of the box is a diamond, one might

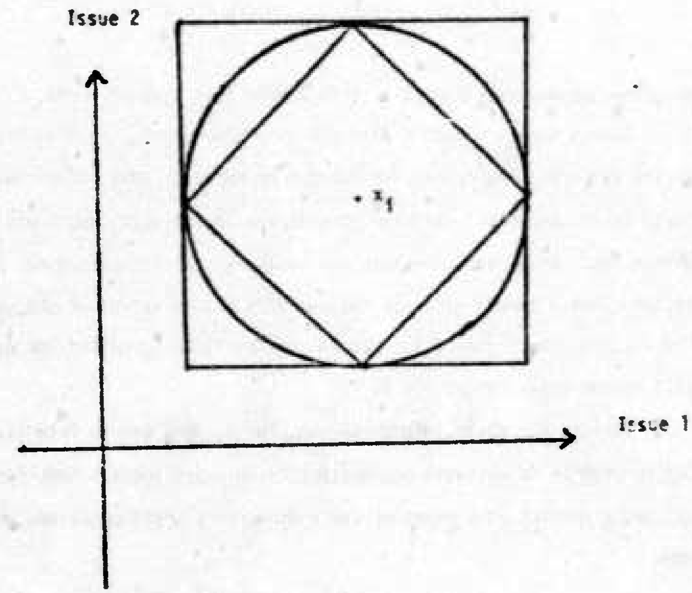


Figure 2.2

suspect that the mathematical structure of ℓ_∞ persons and the ℓ_1 person are related. We will now investigate this relationship between these two norms.

<u>Theorem 2.1</u> In R^2 the ℓ_1 norm and the ℓ_∞ norm are equivalent under a change of variables (e.g. a 45 degree rotation).

For a proof see [35].

Just as significant as the above theorem is the fact that the norms are not equivalent in R^n for $n \geq 3$. In R^3, for example, the diamond will have 6 extreme points (e.g. corners) while a box has 8 extreme points. Thus, no matter how much one rotates the two figures, they will never become "equivalent."

<u>Example 2.4</u>

As we all know, the Euclidean norm is defined as

$$||\xi||^{(2)} \equiv \left[\sum_{j=1}^{n} (\xi^j)^2\right]^{1/2}$$

where the superscript (2) is used to denote it. Alternatively, we will refer to the Euclidean norm as the ℓ_2 norm. Except for property (iv), it is easy to verify that the properties of a norm are satisfied (Property (iv) is a special case of the Minkowski inequality--see page 31 of [22]). Also, it is clear that the indifference contours of this norm are circles (see Figure 2.2).

<u>Example 2.5</u>

In a more general sense we define an ℓ_p norm for $p \geq 1$ as

$$||\xi||^{(p)} \equiv \left[\sum_{j=1}^{n} \left|\xi^j\right|^p\right]^{1/p}$$

where the superscript (p) is used to denote the particular ℓp norm. As

before, the proof of property (iv) of norms follows from the Minkowski inequality. Note that Examples 2.2, 2.3, and 2.4 are special cases when $p = 1, 2,$ and ∞ respectively. The indifference contours are illustrated in Figure 2.1.

<u>Example 2.6</u>

Consider a norm defined as

$$(2.4) \qquad ||\xi|| \equiv (\xi' A \xi)^{1/2}$$

where A is a positive definite matrix. This is the norm used in much of the previous spatial theory analyses (as in [5], [26]).

See Householder [15] for a proof of the fact that this does indeed satisfy the properties (2.2) of a norm. For our purposes, it is sufficient to point out that since A is positive definite one can choose an eigenvector basis such that A can be represented as a diagonal matrix whose elements along the diagonal are its strictly positive eigenvalues (see [5] for a further discussion). By changing the scale along this new basis according to the square root of these eignevalues, the norm (2.4) becomes equivalent to the Euclidean norm (Footnote 18 of [5] also points this out). Thus, the norm (2.4) gives no new mathematical generality to the problem than does a formulation under the simple Euclidean norm.

In summary, this section has introduced various abstract distance functions and has discussed how different behaviors can be related to different functions. Metrics characterized a very general class of different functions which includes norms as an important subclass. In particular, ℓ_p norms give a characterization of a whole class of norms which include the Euclidean norm as a special case. The Euclidean norm case is of course the distance measure which has been considered in previous spatial theory analysis. In

Figure 2.2 we have illustrated the shapes of indifference contours characterized by ℓ_p norms. Although this represents a broad behavior class, the fact that there is a one-to-one correspondence between norms and symmetric convex indifference contours* (see page 132 of [25] for further discussion) indicates that much broader classes of behavior other than ℓ_p norms can be considered by studying problem structures using norms.

*An indifference contour is convex when the set it contains is convex. Convex sets is one of the items to be discussed in the Appendix.

3. Minimizing Total Utility Loss

As indicated in section 1, the spatial analyses of dictatorships have assumed that the dictator wishes to minimize (weighted) total utility loss to the citizens as formulated in problem (1.2).

In this section we will use the concepts of metrics and norms to generalize this problem structure and give results of analysis of these structures. It will also be shown how problem (1.2) is a very special case of our general formulation.

The most general formulation that we consider is:

$$\text{(T1)} \quad \min_{\theta} \sum_{i=1}^{m} C_i\left(\rho_i(x_i, \theta)\right)$$

where

$C_i(\cdot) \equiv$ a non-decreasing function which gives a loss measure for each of the m citizens ($i=1, \ldots, m$);

$\rho_i(x_i, \theta) \equiv$ a metric that measures the distance that citizen i perceives to exist between his position x_i and the dictator's position θ (e.g. the type of metric is allowed to depend on the citizen).

Unfortunately, not much can be said about the general problem (T1). We, therefore, consider the following special case (i.e. more structural problem).

$$\text{(T2)} \quad \min_{\theta} \sum_{i=1}^{m} w_i\, \rho_i(x_i, \theta)$$

The weights w_i are positive scalar constants. In particular, (T2) results as a special case of (T1) when one lets $C_i(z) \equiv w_i z$. Again we will not give any results, but instead we give another special case of (T1).

$$(T3) \quad \mathrm{Min} \sum_{i=1}^{m} C_i\,(\rho\,(x_i, \theta))$$

Unlike (T1), note that (T3) assumes that all the metrics are of the same type (e.g. the type of metric does not depend on the citizen). Such an assumption may indeed be true for various organizations or groups (e.g. people who "think alike" may quite naturally tend to gravitate together). At any rate, the assumption in [5], [24] that the matrix A is independent of each citizen x_i is a special case of the above assumption.

Finally we give a problem, that is a special case of (T2) and (T3), about which we can state a result.

$$(T4) \quad \underset{\theta}{\mathrm{Min}} \sum_{i=1}^{m} w_i\,\rho(x_i, \theta)$$

Note that this problem is a special case of (T2) in that (T4) assumes that the same type of metric ρ applies to all citizens. On the other hand, it follows from (T3) by assuming that $C_i(z) = w_i z$ for each i.

<u>Theorem 3.1</u> If $w_k \geq \sum_{\substack{i=1 \\ i \neq k}}^{m} w_i$, then $\theta^* = x_k$.

<u>Proof</u> (see page 30 of [37])

A point x_k that satisfies the property that $w_k \geq \sum_{\substack{i=1 \\ i \neq k}}^{m} w_i$ is said to be a <u>singular point</u>. Thus the theorem (often called the majority theorem) states that a singular point is an optimal location for the dictator who desires to minimize total utility loss. This is true regardless of the type of metric being considered (e.g. we only assumed that all metrics were of the <u>same unspecified type</u>). The weights w_i can be viewed as either a linear approximation to the loss function $C_i(\cdot)$ of the corresponding citizen x_i or as the dictator's perception of this linear approximation. In the latter case, the weight w_i can be considered as an index of the relative importance

that the dictator views each point x_i. In this case we can think of w_i as a measure of the power of a group located at the point x_i. Thus, the benevolent dictator, who perceives the power of one group to be greater than or equal to the sum of the power of all other groups, will adopt a position identical to that most powerful group. Note that this is true regardless of the relative location x_i of the groups (e.g. citizens).

We now consider the following special case of problem (T1).

$$(T5) \quad \underset{\theta}{\mathrm{Min}} \sum_{i=1}^{m} C_i\,(\|x_i - \theta\|_i)^*$$

The basic difference between this problem and problem (T1) is that a norm is used in (T5) instead of a metric. If C_i is strictly increasing, this makes the problem strictly quasiconvex and thus guarantees that any local optimal solution is globally optimal. Although the existence of an optimal solution can be proved, the optimal solution surprisingly may not be in the convex hull of the points $\{x_1, \ldots, x_m\}$ (e.g. see [31]). (To see why this is surprising see the Appendix for a discussion of the relationship of convex hulls to compromises.). Finally, if $C_i(\cdot)$ is convex then problem (T5) becomes a convex programming problem to which duality theory can be applied. This will be discussed in problem (T8).

Besides having the above structure, problem (T5) has an interesting result in an important special case. In particular, we consider the case where n = 1 (e.g. R^n becomes the real line R^1) such that we are in the one dimensional issue space considered by Hotelling [14], Downs [8], and Tullock [30].

---

*Unlike the use of the superscript $\|\cdot\|^{(p)}$ to denote a particular ℓ_p norm, the use of the subscript $\|\cdot\|_i$ merely indicates that the type of norm is individual for each citizen.

Theorem 3.2 If $C_i(\cdot)$ are concave functions then the optimal location θ^* will be at some point x_i for a problem in R^1.

The proof follows from the observation that all norms are "equivalent" in R^1 and a property of concave functions (see [32]).

Even if the functions $C_i(\cdot)$ are not concave, we still have the following result.

Theorem 3.3 In R^1 problem (T5) will have an optimal location $\theta^* \in$ c.h. $\{x_1, \ldots, x_m\}$.*

Again the proof follows from the "equivalence" of norms in R^1.

By now the reader may suspect that we are examining a sequence of problems with different levels of abstraction. If so, he is right. The interrelationships of these various problems are given in Figure 3.1. The top problem represents the most abstract one with special cases being represented by arrows. Thus, any result for a problem will also be true for any of its special cases. For example, what is true of (T5) is also true of (T6), (T7), (T8), and (T9). On the other hand, we will sometimes

PLACE FIGURE 3.1 ABOUT HERE

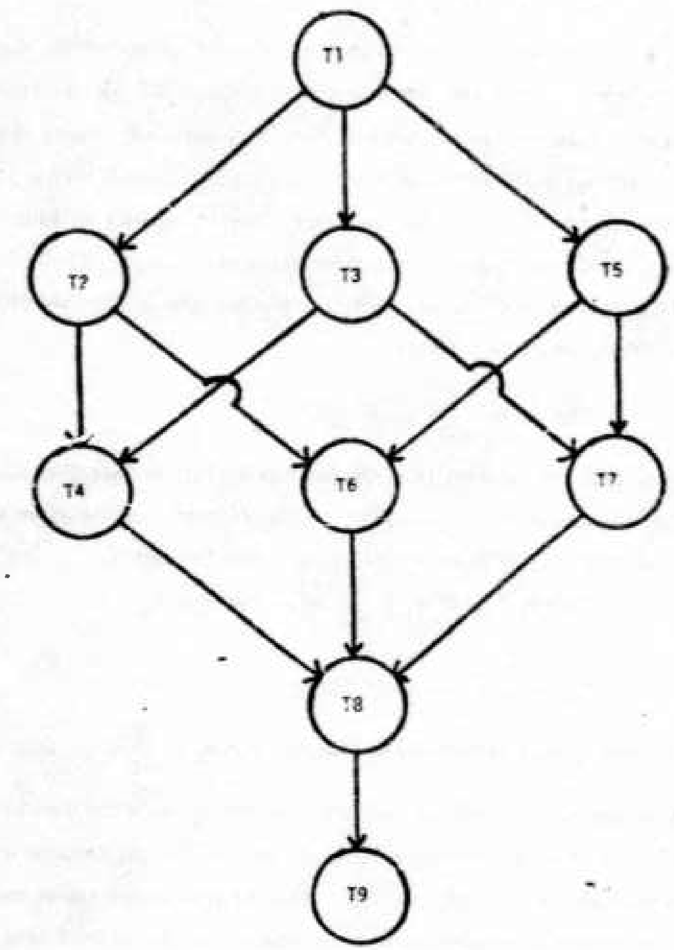
be able to say more about the special cases since they have more structure. This will become evident as we proceed.

We now consider a special case of problems (T2) and (T5).

$$\text{(T6)} \quad \min_{\theta} \sum_{i=1}^{m} w_i \, \|x_i - \theta\|_1$$

---

*The notation c.h. $\{x_1, \ldots, x_m\}$ means the convex hull of the set $\{x_1, \ldots, x_m\}$. See the Appendix for further discussion.



Interrelationship of the Formulations

Figure 3.1

In particular, (T6) is a special case of (T2) in that each metric $\rho_i(\cdot,\cdot)$ is now assumed to be a norm $||\cdot||_i$. On the other hand, (T6) is a special case of (T5) if one lets $C_i(z) = w_i z$. The interpretation of such assumptions have been previously given when discussing problems (T2) and (T5).

Before giving a result for this problem, we first recall a basic property of norms.

<u>Lemma</u> (see page 132 of [25]).

Let $||\cdot||_1$ and $||\cdot||_2$ be two given norms. Then there exists $L_2 > 0$ and $U_2 > 0$ such that for every $\xi \in R^n$ we have

$$L_2 \, ||\xi||_2 \leq ||\xi||_1 \leq U_2 ||\xi||_2 \quad .$$

For a given norm $||\cdot||_k$ we define

$$\bar{U}_i \equiv \text{Min } \{U_i : ||\xi||_i \leq U_i \, ||\xi||_k\} \text{ and}$$

$$\bar{L}_i \equiv \text{Max } \{L_i : ||\xi||_i \geq L_i \, ||\xi||_k\} \ . \text{ If, of course, all norms}$$

are of the same type, then $\bar{L}_i = \bar{U}_i = 1$. Although $\bar{U}_i \geq \bar{L}_i$ in general, it is possible that $\bar{U}_i \leq 1$.

We now use this lemma to state a generalization of the Majority Theorem in the multi-norm problem (T6).

<u>Theorem 3.4</u> If $w_k \geq \sum_{\substack{i=1 \\ i \neq k}}^{m} \bar{U}_i w_i$, then $\theta^* = x_k$.

<u>Proof</u> (see [35]).

Thus, if the norm being used by each citizen is known, the dictator can readily calculate $\bar{U}_1, \ldots, \bar{U}_m$ with respect to a given norm $||\cdot||_k$. Then, given weights w_i, a dictator should locate at x_k if $w_k \geq \sum_{\substack{i=1 \\ i \neq k}}^{m} w_i \ \bar{U}_i$. In particular, if the "power" (e.g. loss) of the k^{th} citizen is greater than or

equal to the weighted sum of the "power" (i.e. loss) of all other citizens (with the weights $\bar{U}_i$ as defined), then the dictator should locate at x_k. Since $\bar{U}_i = 1$ if all norms are of the same type, the above theorem is a generalization of the Majority Theorem.

Now we look at a special case of problems (T3) and (T5):

$$\text{(T7)} \quad \text{Min } \sum_{i=1}^{m} C_i \, (|| \, x_i - \theta||).$$

In particular, (T7) is a special case of (T3) in that the metric $\rho(\cdot,\cdot)$ is now replaced by a norm $||\cdot||$. It is a special case of (T5) in that (T7) assumes that all citizens have the same type of norm.

As given in (1.2), Davis, Hinich, and Ordeshook [5] not only assume that all citizens have the same type of norm but further assume that this norm is $[(x_i - \theta)' \, A \, (x_i - \theta)]^{1/2}$. With respect to generalizing their assumption they state (see page 434 of [5]) that "such a step results in a model whose complexity appears to prohibit the realization of meaningful analytical results. Accordingly, we use a simpler approach." This model (T7), and in fact this whole paper, is in direct contrast to their statement.

Along these lines we now point out how problem (1.2) is a special case of problem (T7). To see this, make the following identifications

$$||x_i - \theta|| = \left[(x_i - \theta)' \, A \, (x_i - \theta) \right]^{1/2} .$$

$$C_i(z) = w(x_i) \, \phi \, (z^2)$$

so that $C_i \, (||x_i - \theta||) = w(x_i) \, \phi \, ((x_i - \theta)' \, A \, (x_i - \theta))$.

Later we will further show how problem (1.4), which is equivalent to (1.2), is a special case of problem (T7.2), which in turn is a special case of problem (T7).

This problem has been considered in [31] and among the results is the

following.

<u>Theorem 3.5</u> If $n \leq 2$ then there exists an optimal solution $\theta^* \in$ c.h. $\{x_1, \ldots, x_m\}$.

In other words, if there are at most two issues then an optimal dictator location is in the convex hull of the citizen's positions (e.g. if there are three citizens, then there is an optimal dictator location in the triangle formed by the three points). This seems reasonable in that the dictator desires to reach a compromise among the citizens (see the Appendix for a further discussion on this point). <u>What is surprising is that when $n \geq 3$ (e.g. at least 3 issues) this convex hull property is not true (see [35]).</u> More specifically, the optimal dictator location may not be in the convex hull of $\{x_1, \ldots, x_m\}$ when we have more than two issues. Moreover, recall that this convex hull property is not true for problem (T5) even when $n = 2$.

Also, recall that for $n = 1$, we discussed the convex hull property in Theorem 3.3. We now consider a more general case where the positions $\{x_1, \ldots, x_m\}$ are collinear (e.g. lie on a straight line L) in R^n. More specifically, we allow the issue space to be multi-dimensional but we consider the case where the points $\{x_1, \ldots, x_m\}$ are collinear in that space. Note that if $n = 1$ (e.g. we are in R^1) then the points $\{x_1, \ldots, x_m\}$ must be collinear. Thus, our present case is a generalization of the R^1 case in that we consider the preferences of citizens on positions that do not lie on the line L. With respect to this more general situation, we get the following result that reduces the problem to one of location on the line L.

<u>Theorem 3.6</u> In problem (T7) consider the case where the points $\{x_1, \ldots, x_m\}$ lie on some line L. Then for every $\theta \notin L$ there exists a $\bar{\theta} \in L$ such that

$$\sum_{i=1}^{m} C_i\,(\|x_i - \bar{\theta}\|) \leq \sum_{i=1}^{m} C_i\,(\|x_i - \theta\|)\ .$$

<u>Pf.</u> (see [35]).

This theorem says that the dictator need only consider points on the line L as possible optimal locations. Thus the problem "essentially reduces" (see [31] for details) to one in R^1 and Theorems 3.2 and 3.3 apply. We can, therefore, state the following result.

<u>Corollary</u> If $\{x_1, \ldots, x_m\}$ are collinear in R^n then an optimal location for problem (T7) in the convex hull of $\{x_1, \ldots, x_m\}$ will exist. Furthermore, if $C_i(\cdot)$ are concave functions, then some x_i will be optimal.

The surprising thing about the above result is that it depends on all citizens having the same type of norm. If, for example, the points $\{x_1, \ldots, x_m\}$ in problem (T5) are collinear, the result is not necessarily true.

<u>Example 3.1</u>

Consider the case of two citizens with locations $x_1 = \begin{pmatrix}2\\0\end{pmatrix}$ and $x_2 = \begin{pmatrix}0\\1\end{pmatrix}$ in R^2. Suppose that citizen x_1 uses the ℓ_∞ norm while citizen x_2 uses the ℓ_1 norm. If the loss of each citizen is proportional to distance with weights $w_1 = 3/2$ and $w_2 = 1$ for citizens x_1 and x_2 respectively, then the dictator's problem becomes

$$\min_{\theta}\ 3/2\|\ x_1 - \theta\|^{(\infty)} + \|x_2 - \theta\|^{(1)}\ .$$

It is easy to verify that every point on the line L through x_1 and x_2 has a strictly higher total loss than the point $\begin{pmatrix}1\\1\end{pmatrix}$. Thus, the optimal location in this case is not on the line L and the problem does not "reduce" to the R^1 case.

The above example and the previous theorems lead to the following conclusion. <u>If the points $\{x_1, \ldots, x_m\}$ are collinear in R^n and if all citizens</u>

have the same norm in problem (T5) (e.g. as in problem (T7)), then the dictator's location problem becomes "equivalent" to a simple location problem in R^1. In general, however, such a reduction in problem (T5) is not possible. Therefore, a careful distinction must be made in problem (T5) as to whether the points $\{x_1, \ldots, x_m\}$ are collinear in R^n or whether the issue space is R^1.

We will now look at the three important special cases of (T7) when the norms are $\ell_1, \ell_2, \ell_\infty$ respectively. We denote these special cases as problems (T7.1), (T7.2), and (T7.∞).

$$\text{(T7.1)} \quad \min_{\theta} \sum_{i=1}^{m} C_i \left(\| x_i - \theta \|^{(1)} \right)$$

This problem is simply one of minimizing total utility loss when the distance measure for all citizens is the ℓ_1 norm. If C_i is concave we get the interesting result that the optimal solution θ^* is at one of a finite number of "intersection points." We will not rigorously define an "intersection point" here (see [21]), but instead we illustrate the concept in Figure 3.2. In R^2 the intersection points are given by the intersection of lines parallel to the axes through each point x_i for $i = 1, \ldots, m$. In R^3 we use planes instead of lines and in general we use hyperplanes*.

Theorem 3.7 Let $\{y_1, \ldots, y_k\}$ be the set of intersection points of the set $\{x_1, \ldots, x_m\}$ where $x_i \in R^n$. Then $k \leq m^n$. If C_i is a concave function for $i = 1, \ldots, m$, then $\theta^* \in \{y_1, \ldots, y_k\}$.

Thus, if each citizen's loss function $C_i(\cdot)$ is concave then some intersection point will be an optimal location for the dictator.

PLACE FIGURE 3.2 HERE

*See [23] for a definition of a hyperplane.

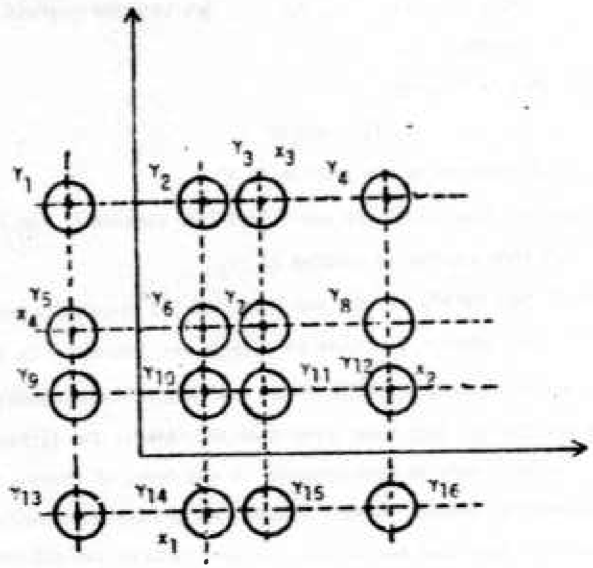


Figure 3.2

We now consider the problem (T7) under the familiar Euclidean norm.

$$\text{(T7.2)} \quad \min_{\theta} \sum_{i=1}^{m} C_i\,(\|x_i - \theta\|^{(2)})$$

It is interesting that the optimal solution(s) for this problem has a property which (as we have pointed out) is not true for (T7) in general.

<u>Theorem 3.8</u> For arbitrary n there exists an optimal solution $\theta^* \in$ c.h. $\{x_1, \ldots, x_m\}$. See [31] for a proof of this result.

Note that by letting

$$C_i(z) \equiv w(x_i)z^2$$

problem (T7.2) reduces to the problem (1.4).

Since (1.4) and (1.2) are equivalent (see section 1 for a discussion), Theorems 3.8 also applies to problem (1.2).

Recall that Davis, Hinich, and Ordeshook [5] obtained a much more specific result for their problem that what we have so far obtained. In particular, by by making various symmetry, unimodality, and marginally increasing assumptions (e.g. see section 1), they have shown that the mean is the optimal dictator location. We have made no such assumptions and have, of course, not arrived at such a specific result. Later, however, as we make more explicit assumptions, we will show that median also can be a natural optimal location for a dictator. Such a result is parallel to the one-dimensional analyses of democracies (see [8], [14], [30]) as well as to the generalizations of this one-dimensional analysis that we give in [34].

Under the ℓ_∞ norm problem (T7) becomes

$$\text{(T7.}\infty\text{)} \quad \min_{\theta} \sum_{i=1}^{m} C_i(\|x_i - \theta\|^{(\infty)}).$$

Recall that in a two dimensional issue space R^2 our theorem in section 2 showed that the $\|\cdot\|^{(\infty)}$ and $\|\cdot\|^{(1)}$ norms are equivalent under a 45 degree rotation. Hence, our previous theorem for optimal location to (T7.1) at intersection points also applies to (T7.∞) after such a rotation if we are in R^2. For R^n with $n \geq 3$ this problem has not been studied (probably because of its lack of applications to plant location theory). A special case of (T7.∞) when $C_i(z) = w_i z$ can be solved and will be considered in our discussion of problem (T8).

We now consider an important special case of problems (T4), (T6), and (T7).

$$\text{(T8)} \quad \min_{\theta} \sum_{i=1}^{m} w_i \|x_i - \theta\|$$

This problem is a special case of (T4) in that a norm is used instead of a metric as a distance measure. From (T6) we get (T8) by assuming that all norms are of the same type. Finally, from (T7) we get (T8) by assuming that $C_i(z) = w_i z$.

Before going into the special cases of (T8) that arise from considering specific norms, we first consider the case where $\{x_1, \ldots, x_m\}$ are collinear along same line L. Besides having the results from Theorem 3.6 and its Corollary, we further have the following result.

<u>Theorem 3.9</u> Suppose that in problem (T8) the points $\{x_1, \ldots, x_m\}$ are collinear along some line L. For this line L specify some direction of increase so that we can relate any two points x_i, x_k in the line L by the relationships $\geq$, $\leq$, $>$, $<$, and $=$.

Then x^* on L is an optimal location iff

$$\sum_{\substack{i:\\ \{x_i < x^*\}}} w_i \le \sum_{\substack{i:\\ \{x_i \ge x^*\}}} w_i$$

and

$$\sum_{\substack{i:\\ \{x_i \le x^*\}}} w_i \ge \sum_{\substack{i:\\ \{x_i > x^*\}}} w_i \; .$$

Furthermore (by Theorem 3.6), these conditions will be satisfied for some $x^* = x_k$.

In the above theorem, the optimal location of the dictator corresponds to a point x^* where the sum of the slopes of the citizens' loss functions to the "left" of the dictator is counterbalanced by the sum of the slopes of the citizens' loss functions to his "right." Roughly speaking, x^* is a point where the "power" of citizens to the "right" are counterbalanced by citizens to the "left." Some x_k will always have this property. Furthermore, when all w_i are equal (or equivalently, when they all equal one), x^* is just the median of the points $\{x_1, \ldots, x_m\}$ along the line L. Again we consider the three special cases of the ℓ_p norm: the ℓ_1 norm $||\cdot||^{(1)}$, the ℓ_2 norm $||\cdot||^{(2)}$, and the ℓ_∞ norm $||\cdot||^{(\infty)}$.

First, under the ℓ_1 norm, we have the following problem.

$$\text{(T8.1)} \quad \min_{\theta} \sum_{i=1}^{m} w_i \, || x_i - \theta ||^{(1)}$$

This nonlinear problem has the interesting property of possible reformulation as a linear program [36]. As a linear program the optimal solution is easily

determined via the Simplex method. Although such a reformulation can be made in general for R^n, for simplicity we illustrate the approach for problems in R^2.

Example 3.2 .

In R^2 problem (T8.1) becomes

$$\min_{\theta^1, \theta^2} \sum_{i=1}^{m} w_i \left(|x_i^1 - \theta^1| + |x_i^2 - \theta^2| \right) .$$

By introducing other variables and exploiting properties of absolute values, we get the problem

$$\min_{\substack{\theta^1, \theta^2, y_i^1, y_i^2\\ i = 1, \ldots, m}} \sum_{i=1}^{m} w_i y_i^1 + w_i y_i^2$$

s.t.

$$y_i^1 \ge x_i^1 - \theta^1$$
$$y_i^1 \ge \theta^1 - x_i^1$$
$$y_i^2 \ge x_i^2 - \theta^2$$
$$y_i^2 \ge \theta^2 - x_i^2 \qquad \text{for } i = 1, \ldots, m.$$

The above problem is a linear program whose optimal solution can be readily determined via the Simplex method.

Although the above example illustrates a method of finding the optimal solution, the process provides little insight into the nature of the optimal solution. Recall, however, that from our study of problem (T7.1) we pointed out that an optimal location will exist at some intersection point. We can now strengthen this result through the following theorem [?].

First a relatively simple result is given.

<u>Theorem 3.11</u> If the points x_i are not collinear then there exists a <u>unique</u> optimal solution. The proof [19] follows from the fact that $\sum_{i=1}^{m} w_i \,||\, x_i - \theta ||^{(2)}$ is strictly convex.

Also, the following result is quite remarkable.

<u>Theorem 3.12</u> Let $\phi \equiv \underset{\theta}{\mathrm{Min}} \sum_{i=1}^{m} w_i \,||\theta - x_i||^{(2)}$ be called the primal problem. Now consider the dual program to the above problem*.

$$\chi = \underset{y_1, \ldots, y_m}{\mathrm{Max}} \sum_{i=1}^{m} \langle x_i, y_i \rangle$$

s.t.

$$||y_i||^{(2)} \leq w_i \text{ for } i=1, \ldots, m$$

$$\sum_{i=1}^{m} y_i = 0$$

Then $\phi=\chi$ and the optimal solutions to the above problems are related as follows:

$$y_i^* = \begin{cases} \dfrac{w_i\,(x_i - \theta^*)}{||\theta^* - x_i||^{(2)}} & \text{if } \theta^* \neq x_i \\[2ex] -\sum\limits_{\substack{k=1 \\ k\neq i}}^{m} y_k^* & \text{if } \theta^* = x_i, \text{ for } i=1, 2, \ldots, m^{**}. \end{cases}$$

---

*The inner product $\langle x_i, y_i \rangle$ has its usual definition as $\sum_{j=1}^{n} x_i^{\,j}\, y_i^{\,j}$.

**Since θ^* will equal at most one x_i, no confusion concerning these cases exists.

See [19] for further discussion and a proof of the above duality theorem. For a generalization of the theorem to problem (T8) see [37]. Also, for a generalization to problem (T5) see [33]. For our purposes of understanding and discussing the concept of duality, we limit ourselves to problem (T8.2) and the above theorem.

In physics the primal problem can be interpreted as finding the point of minimum potential energy. One can think of this by considering the problem in R^2 and by imagining a smooth (frictionless) table top with holes at the points x_i. Then we get m strings, put the i^{th} string through the hole x_i, and attach a weight w_i to the end of the string hanging under the table. Finally, we tie all m strings together into one knot that is free to move on the top of the table. Since there is no friction, the knot will come to rest at the optimal location θ^*.

In physics there is a duality between potential energy and force. In particular, we can view the problem of minimizing potential energy as one of finding those set of forces $\{y_1^*, \ldots, y_m^*\}$ along the strings 1, ..., m respectively that sum to zero (e.g. are in equilibrium). The dual problem solves for this set of optimal forces.

The interpretation of these forces in political terms is especially interesting. In particular, a dictator located at θ^* will "feel" a force on him y_i^* for i=1, ..., m. Unless $\theta^* = x_i$, the magnitude of this force will be w_i.

Since $\theta^* = \chi$ (i.e. no duality gap) and since the relationship between the optimal primal and dual variables are necessary and sufficient, one can derive the following theorems for optimal locations (see [33]).

<u>Theorem 3.12</u> A solution θ (not equal to any x_i) to the primal is optimal iff

$$\sum_{i=1}^{m} w_i \frac{(x_i - \theta)}{||\theta - x_i||^{(2)}} = 0 \quad .$$

Equivalently, letting e_j be the j^{th} unit vector in R^n, this condition can be written as

$$\sum_{i=1}^{m} w_i \cos \langle e_j , x_i - \theta = 0 \quad \text{for } j=1, \ldots, n^*.$$

Note that the cosine terms in the above condition takes account of the relative positions of the points x_i in R^n.

Alternately, for a solution $\theta = x_i$, we have the following result:

<u>Theorem 3.14</u> A solution $\theta = x_i$ is optimal iff

$$\left|\left| \sum_{\substack{k=1 \\ k \neq i}}^{m} w_k \frac{(x_k - \theta)}{||\theta - x_k||^{(2)}} \right|\right|^{(2)} \leq w_i \quad .$$

It is perhaps easiest to interpret the above theorem in terms of forces. In particular, if the dictator locates at some point $\theta = x_i$, then the force that citizen x_k (for $k \neq i$) is $\dfrac{w_k (x_k - \theta)}{||\theta - x_k||^{(2)}}$.

The vector sum of all such forces is

---

*$\cos \langle e_j , x_i - \theta$ is the cosine of the angle between the vectors e_j and $x_i - \theta$.

$$\sum_{\substack{k=1 \\ k \neq i}}^{m} w_k \frac{(x_k - \theta)}{||\theta - x_k||^{(2)}}$$

and this sum has the magnitude given by the left expression in Theorem 3.14. On the other hand, the magnitude of the force extended by citizen x_i is w_i. Thus, the theorem says that x_i is optimal iff the force w_i is greater than or equal to the magnitude of the sum of forces of all other citizens.

Again, the relative positions of the points x_i play an important role in the above result. Using the triangle inequality for norms we can easily derive the following sufficient condition which is true regardless of the relative position of the points x_i.

<u>Corollary</u>

$$\text{If} \quad \sum_{\substack{k=1 \\ k \neq i}}^{m} w_k \leq w_i \qquad \text{then} \quad \theta^* = x_i \quad . \;.$$

This, of course, is identical to the Majority Theorem 3.1, which we gave for a much more abstract problem (e.g. see problem (T4). Comparing Theorem 3.14 to Theorem 3.1 one can readily see how the additional structure in problem (T8.2) over problem (T4) leads to a more powerful result.

We now terminate our discussion of problem (T8) by considering the case of the L_∞ norm.

$$(T8.\infty) \quad \underset{\theta}{\text{Min}} \sum_{i=1}^{m} w_i \, || x_i - \theta ||^{(\infty)}$$

As discussed previously, the results for (T8.1) and (T8.∞) are "equivalent" in R^2 after one makes a change of variables to effect a 45 degree rotation. We will not dwell on the details of this "equivalence." Instead we will

illustrate how this problem can be reformulated as a linear program. Although such a reformulation can be made in R^n, for simplicity we consider the problem in R^2.

<u>Example 3.3</u>

In R^2 problem (T8.=) becomes

$$\min_{\theta^1, \theta^2} \sum_{i=1}^{m} w_i \, \mathrm{Max} \, \{ | x_i^1 - \theta^1 | , | x_i^2 - \theta^2 | \} \quad .$$

Using various absolute value "tricks", we get the problem

$$\min_{\substack{\theta^1, \theta^2, y \\ i=1, \ldots, m}} \sum_{i=1}^{m} w_i y_i$$

s.t.

$$y_i \geq x_i^1 - \theta^1$$
$$y_i \geq \theta^1 - x_i^1$$
$$y_i \geq x_i^2 - \theta^2$$
$$y_i \geq \theta^2 - x_i^2 \quad .$$

for $i = 1, \ldots, m$.

This is a linear program which can be solved via the Simplex method.

Finally, we come to the last problem in our heirarchical classification.

$$\text{(T9)} \qquad \min_{\theta} \sum_{i=1}^{m} \| x_i - \theta \|$$

Note that (T9) is a special case of (T8) that results when $w_i = 1$ for $i=1, \ldots, m$ (e.g. or, in general, when $w_1 = w_2 = \ldots = w_m$).

Again, the collinear case, gives us an important special result.

<u>Theorem 3.15</u> If $\{x_1, \ldots, x_m\}$ are collinear on some line L then x^* is the median of the points $\{x_1, \ldots, x_m\}$ over the line L.

The proof follows from our discussion following Theorem 3.9.

Another result which also illustrates the basic importance of the median is the following theorem for the non-collinear case where the norm is of the ℓ_1 type.

<u>Theorem 3.16</u> In problem (T9.1) the optimal solution θ^* is at the multi-dimensional median. More specifically, the j^{th} coordinate θ^{j*} of θ^* is the median of the points $\{x_1^j, x_2^j, \ldots, x_m^j\}$. (The proof of this this theorem follows from Theorem 3.10).

Thus, the dictator adopts a median position on each of the issues. Note that the position on the issues are independent of one another. His optimal location at the (multi-dimensional) median is in direct contrast to his location at the mean in [5]. There is no question of who is more correct. One can only ask what set of assumptions apply to the particular situation being considered.

As per problem (T9.=) we merely point out that after rotating the position 45 degrees, the multi-dimensional median result of the ℓ_1 norm case applies.

Finally, for problem (T9.2) we get an interesting graphical solution procedure that yields the optimal solution to the problem in R^2. Instead of reviewing this graphical technique here, we simply refer the reader to [19]. Note that this technique does not have any direct extension to the case R^3 or to the case of weighted distance (e.g. problem (T8.2)). Thus, various

papers have been written to handle these more general cases (for example, see [18], [20], and [21]).

For a summary of the main results in this section see Figure 3.3 which associates theorems with the problem structure illustrated in Figure 3.1.

PLACE FIGURE 3.3 HERE

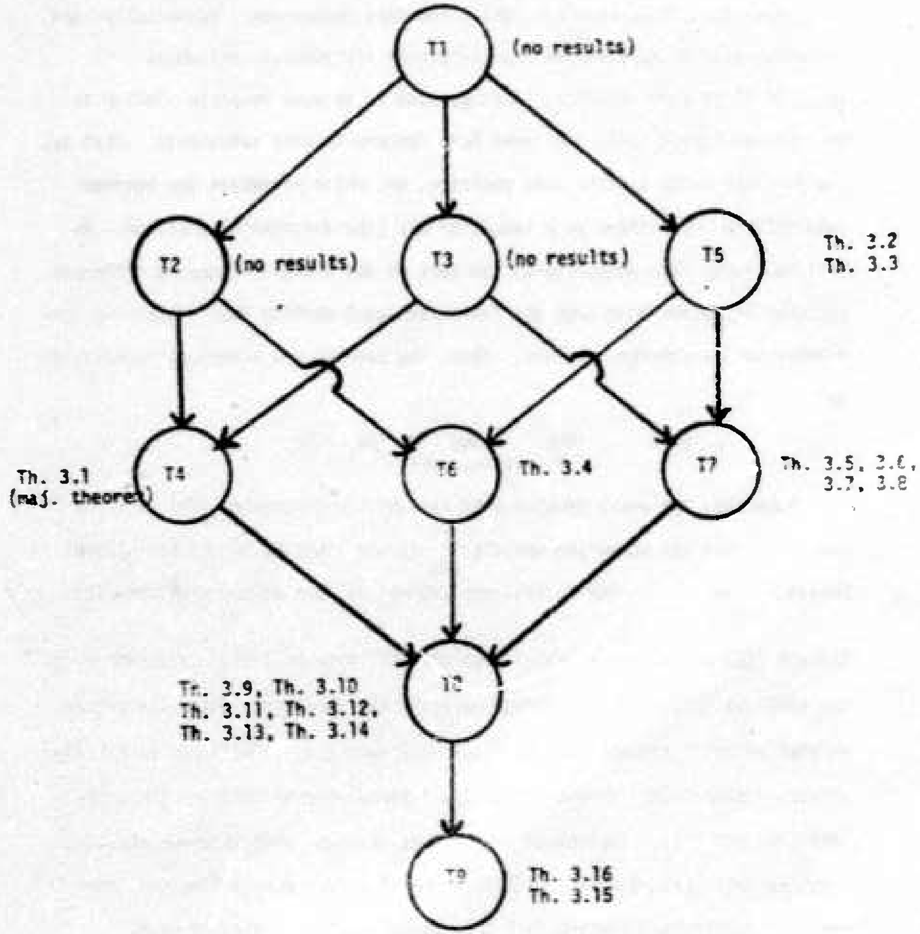


Figure 3.3

4. Minimizing Maximum Utility Loss

Recently in location theory the problem of locating emergency facilities (e.g. hospitals, fire stations, etc.) has been considered. Essentially, the criterion used is to minimize the maximum of all possible distances (e.g. time) to some disaster. This problem is in some respects similar to the one considered in [5] -- only here concern is with extremists. That is, the dictator wants to find some position, θ^*, which minimizes the maximum loss felt by any citizen as a result of his [the dictator's] position. As will be shown, this objective on the part of the dictator leads to different optional locations than does the "minimize total utility loss" objective considered in the previous section. Thus, the problem has a typical formulation as

$$\text{(M5)} \qquad \underset{\theta}{\text{Min}} \quad \underset{i \in \{1,\ldots,m\}}{\text{Max}} \quad \|x_i - \theta\| \quad .$$

Note that the above problem (M5) is similar to problem (T9) with the exception that the summation operator $\sum_{i=1}^{m}$ is now replaced by the maximizing operator $\underset{i \in \{1,\ldots,m\}}{\text{Max}}$. Making this replacement in each of the problems (T1) through (T9) we get a new set of problems (M1) through (M9). Furthermore, the problems (M1) through (M9) have exactly the same hierarchical structure as problems (T1) through (T9) as given in Figure 3.1. We will not explicitly discuss problems (M1) through (M7), but instead we will consider the problems (M3) and (M9). The reason for this is that not much is known about problems (M1) through (M7). (The theorems of convex programming can, however, be applied to problems (M5) through (M9)). On the other hand, problem (M5) falls into a class of problems generally known as Spherical

Covering Problems. As with the Weber problem, this type of problem has a long and interesting history (see [9] for a discussion).

Its relation to the dictator problem is especially interesting and, as we have seen above, leads to a whole new class of problems. In particular, the problem is one of a dictator who wants to pick a position θ^* that minimizes the maximum utility loss (e.g. "unhappiness") of all the citizens. Such a criterion clearly caters to the citizens who are at extreme positions on issues.

Assuming the Euclidean norm, the dictator's problem (M9) becomes

$$\text{(M9.2)} \qquad \underset{\theta}{\text{Min}} \quad \underset{i \in \{1,\ldots,m\}}{\text{Max}} \quad \|x_i - \theta\|^{(2)} \quad .$$

Geometrically this can be interpreted as finding the center of the smallest sphere (e.g. circle or ball) that encloses the points $\{x_1, x_2, \ldots, x_m\}$. (For problem (M8.2) we must consider using an ellipse.). In R^2 the solution is immediate from elementary plane geometry. In general, the problem is not so simple. For further discussion on this point we refer the reader to [9].

Assuming the ℓ_1 norm, we get the problem

$$\text{(M9.1)} \qquad \underset{\theta}{\text{Min}} \quad \underset{i \in \{1,\ldots,m\}}{\text{Max}} \quad \|x_i - \theta\|^{(1)}$$

Similar to (M9.2) this problem can be interpreted as finding the center of the smallest diamond enclosing the points $\{x_1, \ldots, x_m\}$. For a further discussion of the geometry of this problem see [11]. Furthermore, this problem can be reformulated as a linear program [6]. We will now consider such a reformulation for the more general problem (M8.1). In particular, we illustrate the reformulation for a problem in R^2.

Example 4.1 In R^2 problem (M9.1) becomes

$$\min_{\theta^1,\theta^2} \max_{i\in\{1,\dots,m\}} w_i\left(|x_i^1 - \theta^1| + |x_i^2 - \theta^2|\right) .$$

As before we can introduce new variables to get the following linear programming problem*.

$$\min_{\theta^1,\theta^2,\xi} \xi$$

s.t.

$$\frac{\xi}{w_i} + \theta^1 + \theta^2 \geq + x_i^1 + x_i^2$$

$$\frac{\xi}{w_i} + \theta^1 - \theta^2 \geq x_i^1 - x_i^2$$

$$\frac{\xi}{w_i} - \theta^1 + \theta^2 \geq - x_i^1 + x_i^2$$

$$\frac{\xi}{w_i} - \theta^1 - \theta^2 \geq - x_i^1 - x_i^2$$

for $i=1, \dots, m$.

It is interesting to note that for problem (M9.1) we can obtain a further simplification to the following problem with three variables and four constants.

$$\min_{\theta^1,\theta^2,\xi}$$

s.t.

$$\xi + \theta^1 + \theta^2 \geq b_1$$

*We can assume without loss of generality that $w_i > 0$.

$$\xi + \theta^1 - \theta^2 \geq b_2$$
$$\xi - \theta^1 + \theta^2 \geq b_3$$
$$\xi - \theta^1 - \theta^2 \geq b_4$$

Now we come to the problem

$$\text{(M9.}\infty\text{)} \qquad \min_{\theta} \max_{i\in\{1,\dots,m\}} \| x_i - \theta \|_{(\infty)} .$$

This problem has a geometric interpretation as finding the center of the smallest cube (e.g. square in R^2) containing the points $\{x_1, \dots, x_m\}$. In the more general problem,

$$\text{(M8.}\infty\text{)} \qquad \min_{\theta} \max_{i\in\{1,\dots,m\}} w_i \| x_i - \theta \|_{(\infty)}$$

we can imagine using rectangles instead of squares, etc.

We will now consider a reformulation of the above problem. For simplicity, we again illustrate the process in R^2.

Example 4.2. In R^2 problem (M8.∞) becomes

$$\min_{\xi,\theta^1,\theta^2} \max_{i\in\{1,\dots,m\}} w_i \max\left[|x_i^1 - \theta^1| , |x_i^2 - \theta^2|\right]$$

Using the usual substitutions, it is easy to verify that this is equivalent to the linear program

$$\min_{\xi,\theta^1,\theta^2} \xi$$

s.t.

$$\xi + w_i \theta^1 \geq w_i x_i^1$$
$$\xi - w_i \theta^1 \geq - w_i x_i^1$$
$$\xi + w_i \theta^2 \geq w_i x_i^2$$
$$\xi - w_i \theta^2 \geq - w_i x_i^2$$

for $i=1,\dots,m$.

For the problem (M9.∞) (e.g. $w_i = 1$ for all i), we can obtain the simpler problem

$$\min_{\xi,\, \theta^1,\, \theta^2} \xi$$

s.t.

$$\xi + \theta^1 \geq b_1$$
$$\xi - \theta^1 \geq b_2$$
$$\xi + \theta^2 \geq b_3$$
$$\xi - \theta^2 \geq b_4$$

5. Conclusions and Observations

This paper has presented a methodology that can be applied to all levels of group decision making--from small committees to countries. In part it is a generalization of some recent work in spatial theory (e.g. [5], [24]). Our general point of view about this previous work is that although it blazes a new and exciting path, its models are not general enough to capture many important aspects of the "real world." To overcome this difficulty we have defined a heirarchical classification of problems with various levels of abstraction into which their problem becomes a very special case.

Such an approach is important since the higher the level of abstraction, the less one need assume about the structure of the problem. On the other hand, the more that one is prepared to assume about the structure of the problem, the stronger the assertions he is able to make about behavior in such a problem. One good example of this point comes from considering problems (T4) and Theorem 3.1 versus problem (T8.2) and Theorem 3.12.

One of the principle reasons for the generality in this paper is the approach used to characterize preference of the citizens. This point is essentially one of considering various ways that a citizen might perceive the "distance" between two positions in an issue space. Rather than limit ourself to the classic Euclidean distance measure, we introduced the mathematical concept of a metric and a norm from Functional Analysis. The generality of this approach is evident from the fact that there is a one-to-one correspondence between norms and all possible convex symmetric indifference

contours. Furthermore, we pointed out how two of these norms (e.g. ℓ_1 and ℓ_∞) may be just as important (if not more so) than the Euclidean distance norm. These two norms have some important properties which are reflected in the theorems and the examples. Although we cannot cover these important properties in this section, one which stands out is the new significance given to the "median" as an optimal position as opposed to the mean. This is a phenomena which also surfaces in our analysis of democracies [34] in which we extend the one-dimensional results of Hotelling [14], Downs [8], and Tullock[30].

Besides generalizing the concept of distance perception in an issue space, we also considered two different but perfectly reasonable objectives that a benevolent dictator might have. The first objective, which follows [5], is to assume that the dictator wishes to minimize total utility loss. This is considered in section 3. On the other hand, section 4 considers the possibility that the dictator might want to minimize maximum utility loss of the citizens. This is a new critereon which gives somewhat different results for his optimal location.

Finally, we wish to conclude with the observation that the results and methodology of this paper raise a number of additional theoretical and application questions. We leave it to the reader's imagination as to what forms such questions should take.

REFERENCES

1. Arrow, K. Social Choice and Individual Values (2nd ed.). New Haven: Yale, 1963.

2. Attneave, F., "Dimensions of Similarity," American Journal of Psychology. 1950, 63, 516-566.

3. Baumol, W. J. Economic Theory and Operations Analysis. Prentice-Hall, Englewood Cliffs, 1965.

4. Black, D. The Theory of Committees and Elections. London: Cambridge, 1958.

5. Davis, O. A., Hinich, M. J., Ordeshook, P. C., "An Expository Development of a Mathematical Model of the Electoral Process, The American Political Science Review Vol. LXIV, No. 2, June, 1970, 426-448.

6. Dearing, P. M. and R. L. Francis, "A Network Flow Solution to a Multifacility Minimax Location Problem Involving Rectilinear Distances," unpublished.

7. Downs, A., "An Economic Theory of Political Action in a Democracy," Journal of Political Economy, 1957, 65, 135-150.

8. Downs, A. An Economic Theory of Democracy. New York: Harper, 1957.

9. Elzinga, D. J. and D. W. Hearn, "The Minimum Covering Sphere Problem," Management Science, September 1972, 19, 96-104.

10. Fischer, W. and H. C. Micko, "More About Metrics of Subjective Spaces and Attention Distributions," Journal of Mathematical Psychology, 1972, 9, 36-54.

11. Francis, R. L., "A Geometrical Solution Procedure for a Rectilinear Distance Minimax Location Problem," unpublished Technical Note.

12. Gass, S. I. Linear Programming, McGraw-Hill, New York, 1969.

13. Goldberg, R. R. Methods of Real Analysis. Blaisdell, Watham, 1964.

14. Hotelling, H. "Stability in Competition," Economic Journal, 1929, 39, 41-57.

15. Householder, A. S. The Theory of Matrices in Numerical Analysis. Blaisdell, New York, 1965.

16. Hyman, R. and A. Well, "Judgements of Similarity and Spatial Models," Perception and Psychophysics, 1967, 2, 233-248.

17. Kantorovich, L. V. and G. P. Akilov. Functional Analysis in Normed Spaces. Macmillan, New York, 1964.

18. Katz, N., "On the Convergence of a Numerical Scheme for Solving Some Location Equilibrium Problems," SIAM Journal of Applied Math, 1969, 17, 1224-1231.

19. Kuhn, H. W., "On a Pair of Dual Nonlinear Programs," in J. Abadie (ed.), Nonlinear Programming, John Wiley, New York, 1967, 37-54.

20. Kuhn, H. W. and R. E. Kuenne, "An Efficient Algorithm for the Numerical Solution of the Generalized Weber Problem in Spatial Economics," Journal of Regional Science, 1962, 4, 21-33.

21. Love, R. F., "Locating Facilities in Three-Dimensional Space by Convex Programming," Naval Research Logistics Quarterly, 1969, 16, 503-516.

22. Luenberger, D. G. Optimization by Vector Space Methods. John Wiley, New York, 1969.

23. Mangasarian, O. Nonlinear Programming. McGraw-Hill, New York, 1969.

24. Ordeshook, P. C., "Extensions to a Model of the Electoral Process and Implications for the Theory of Responsible Parties," Midwest Journal of Political Science, Feb. 1970, Vol. XIV, No. 1, 43-70.

25. Rockafellar, R. T. Convex Analysis. Princeton, 1970.

26. Shepard, R., "Attention and the Metric Structure of the Stimulus Space," Journal of Mathematical Psychology. 1964, 1, 54-87.

27. Smithies, A., "Optimal Location in Spatial Competition," Journal of Political Economy, 1941, 49, 423-429.

28. Stokes, D., "Spatial Models of Party Competition," American Political Science Review, 1963, 57.

29. Thorson, S. J. and R. E. Wendell, "Spatial Analysis of Electoral Behavior," (in preparation).

30. Tullock, G. Toward a Mathematics of Politics. Ann Arbor, Michigan, 1968.

31. Wendell, R. E. and A. P. Hurter, "Location Theory, Dominance, and Convexity," Operations Research (to appear).

32. Wendell, R. E. and A. P. Hurter, "Optimal Location on a Network," Transportation Science, November 1972, 6.

33. Wendell, R. E. and E. L. Peterson, "Duality in Generalized Location Problems," Location Theory Session, Joint National Meeting of ORSA, TIMS, and AIIE, November 1972.

34. Wendell, R.E. and S.J. Thorson, "Some Generalizations of Social Decisions Under Majority Rule," (submitted for publication).

35. Wendell, R. E. and S. J. Thorson, "Location Theory and The Social Sciences: Optimal Decisions for a Committee or a Country," Location Theory Session, 43rd National Meeting of the Operations Research Society of America, May, 1973.

36. Wesolowsky, G. O. and R. L. Love, "The Optimal Location of New Facilities Using Rectangular Distance," Operations Research, 1971, 19, 124-129.

37. Witzgall, C. Optimal Location of a Central Facility: Mathematical Models and Concepts. National Bureau of Standards Report 8388, Gaithersberg, Maryland, 1965.

APPENDIX

Convexity and Optimal Solutions

In this section we review some of the mathematical concepts used in this paper*. These concepts are well known in the optimization literature and we refer the reader to [23] for a further discussion of them.

Consider a set S of points in R^n.

Definition: The set S is said to be convex if for arbitrary $x_1 \in S$, $x_2 \in S$ and $0 \leq \lambda \leq 1$ we have $\lambda x_1 + (1 - \lambda) x_2 \in S$.

That is, in an issue space R^n, a set of positions S is convex if for any two positions in S their weighted average (with positive weights that sum to one) is also in S. Geometrically this means that a set S is convex if for any two points x_1 and x_2 in the set we have all points on the line segment connecting x_1 and x_2 also in the set.

We now give an equivalent condition for a set to be convex.

Theorem A set S is convex iff for any K points $\{x_1, \ldots, x_K\}$ from S we have that

$$\sum_{k=1}^{K} \alpha_k x_k \in S \qquad \text{where } \alpha_k \geq 0 \text{ and } \sum_{k=1}^{K} \alpha_k = 1.$$

Since when K=2 the above condition reduces to the usual definition of a convex set, it is at first surprising to see that the two conditions are equivalent.

---

*The notation in this Appendix is somewhat different than the notation in other sections of this paper and the two should not be confused.

One of the reasons for giving the above theorem is to help the reader obtain a better understanding of the definition of a convex hull.

Definition: The convex hull of a set S, denoted as c.h.S, is the set

$$\{x : x = \sum_{k=1}^{K} \alpha_k x_k, \alpha_k \geq 0, \sum_{k=1}^{K} \alpha_k = 1, x_k \in S \text{ for } k = 1, \ldots, K\}.$$

In other words, the convex hull of S is the set of all of those vectors x that can be expressed as $\sum_{k=1}^{K} \alpha_k x_k$ for some $\alpha_1, \ldots, \alpha_K \geq 0$, $x_1, \ldots, x_K \in S$ where $\sum_{k=1}^{K} \alpha_k = 1$. Equivalently, we give another characterization of a convex hull.

Theorem The convex hull of a set S, denoted as c.h.S, is the intersection of all the convex sets containing S.

In particular, it can be thought of as the smallest convex set containing S. Given a set of citizen's positions $\{x_1, \ldots, x_m\}$, the convex hull of $\{x_1, \ldots, x_m\}$ might be regarded as the set of "direct compromises" among these positions. This is illustrated in the following example.

Example

In the case when $m = 3$ suppose that the positions of x_1, x_2, and x_3 are given by the vectors $\begin{pmatrix}1\\1\end{pmatrix}$, $\begin{pmatrix}1\\0\end{pmatrix}$, and $\begin{pmatrix}0\\1\end{pmatrix}$ respectively. Figure A.1 depicts this case. The convex hull of these three points is the triangle (including its interior) formed by them. From the theory of convexity we assert that any point y in this triangle can be expressed as follows:

$$y = \lambda_1 x_1 + \lambda_2 x_2 + \lambda_3 x_3$$

where $\lambda_1 + \lambda_2 + \lambda_3 = 1$ and $\lambda_1, \lambda_2, \lambda_3 \geq 0$.

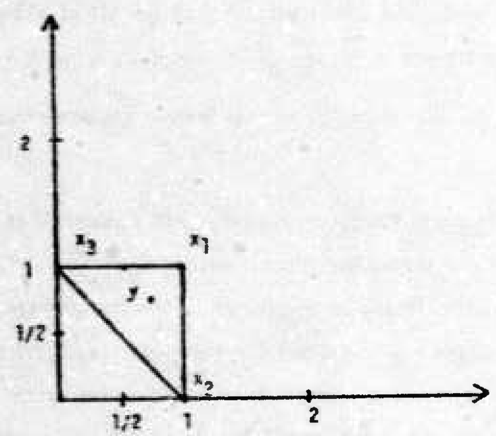


Figure A.1

For example, $\begin{pmatrix}3/4\\3/4\end{pmatrix} = 1/2\begin{pmatrix}1\\1\end{pmatrix} + 1/4\begin{pmatrix}1\\0\end{pmatrix} + 1/4\begin{pmatrix}0\\1\end{pmatrix}$.

PLACE FIGURE A.1 ABOUT HERE

In this case, one might interpret the point $\begin{pmatrix}3/4\\3/4\end{pmatrix}$ as the position resulting when citizen x_1 gets 1/2 of his own way while citizens x_2 and x_3 each get 1/4 of their own way. Thus the point 3/4 can be viewed as a "direct compromise" among citizens x_1, x_2, and x_3 with relative weights 1/2, 1/4, and 1/4 respectively.

Definition: An extreme point x of a convex set S is a point having the following property: for any $x_1 \in S$, $x_2 \in S$, and $0 < \lambda < 1$ where $x = \lambda x_1 + (1 - \lambda) x_2$ we have $x_1 = x_2 = x$.

For example, the extreme points of a rectangle are its four corners and the extreme points of a circle are the points on its circumference. In Figure A.1 the extreme points of the triangle are the points x_1, x_2, and x_2.

Definition: Consider a function f(x) defined on a subset S of R^n into R^1. A mathematical program* is an optimization problem of the form

$$\text{(MP)} \qquad \min_{x \in S} f(x) \quad .$$

Definition: A point x^* is said to be the global optimal solution (e.g. global minimum) of (MP) if $f(x^*) \le f(x)$ for all x in S.

*Although a more mathematically correct definition is to use infimum (Inf) instead of Min, we will not worry about the distinction here.

Because of the possibility of various nonlinearities in $f(x)$ and/or the possibility that S may not be convex, we further define another type of optimal solution.

Definition: A point x^* is said to be a local optimal solution (e.g. local minimum) if there exists some $\delta > 0$ such that $f(x^*) \leq f(x)$ for all x in the set $S \cap \{x : \|x - x^*\| \leq \delta\}$.

In certain important classes of mathematical programs, various properties about the optimal solution can be asserted. To characterize such classes of programs we now make the following definition.

Definition: Consider a function $f(x)$ defined on a convex set S in R^n. Such a function is said to be concave if for every $x_1 \in S$, $x_2 \in S$, and $0 \leq \lambda \leq 1$ we have $f(\lambda x_1 + (1-\lambda)x_2) \geq \lambda f(x_1) + (1-\lambda) f(x_2)$. Alternately, the function is said to be convex if for every $x_1 \in S$, $x_2 \in S$, and $0 \leq \lambda \leq 1$ we have $f(\lambda x_1 + (1-\lambda) x_2) \leq \lambda f(x_1) + (1-\lambda) f(x_2)$. If for every $x_1 \neq x_2$ and $0 < \lambda < 1$ we further have $f(\lambda x_1 + (1-\lambda)x_2) < \lambda f(x_1) + (1-\lambda) f(x_2)$, then $f(x)$ is said to be strictly convex. (Similarly, we can defin strictly concave.)

Roughly speaking, convex functions can be thought of as "U" shaped and concave functions as upside-down "U" shaped.

When S is convex and $f(x)$ is concave over S in (MP), the resulting problem is called a concave program. The following is a basic result for concave programs.

> Theorem If (MP) is a concave program for which an optimal solution exists*, then an optimal solution occurs at some extreme point of S.

---

*We avoid some of mathematical properties of the set S (e.g. compact).

From the above theorem we conclude that in concave programs it is sufficient to look for the global optimal solution over the set of extreme points. If, for example, $S = \{x : Ax \leq b\}$ where A is an $m \times n$ matrix and $b \in R^m$, then only a finite number of such extreme points exist.

If, on the other hand, $f(x)$ is convex over a convex set S in (MP), then the resulting problem is called a convex program. One of the main results for convex programs is the following.

> Theorem If (MP) is a convex program, then any local optimal solution is also a global optimal solution. Furthermore, if $f(x)$ is strictly convex, then the global optimal solution is unique.

Many of the problems in location theory turn out to be convex programs. Thus, in particular, the above theorem applies. There are, however, a number of other theorems which could be brought to bear on such problems. Among these theorems, the ones concerning Lagrangian multipliers and duality are especially interesting. Although we will not discuss these theorems here, we will include some discussion of their application in this paper.

In some important special cases (e.g. as we will see) location problems can be reformulated as linear programs (e.g. when $f(x) = \sum_{j=1}^{n} c^j x^j$ and $S = \{x : Ax \leq b\}$). Linear programs have the unique property of being both convex and concave programs. Thus, it is only necessary to search for the optimal solution over the finite set of extreme points until you find one which is locally (and therefore globally) optimal. One well known method for doing this is the Simplex algorithm. Also important in linear programming is the ability to perform post-optimal sensitivity and parametric analyses. For a further discussion of this, we refer the reader to any

standard linear programming book (e.g. see [12]).

For some problems it is important to characterize other classes of functions f(x) in order to exploit their properties. We will only consider one such class.

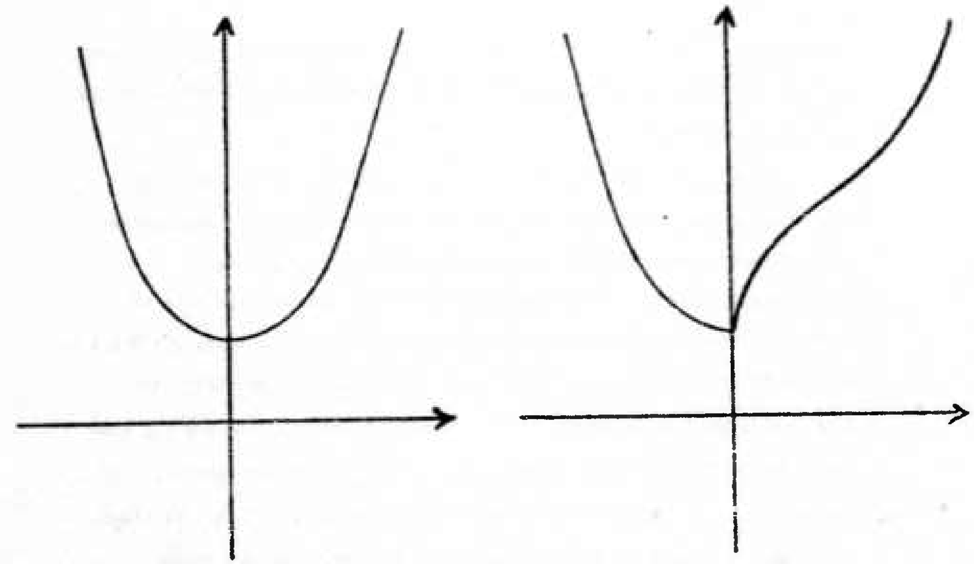
Definition: A function f(x) is said to be strictly quasiconvex over the convex set S when for every $x_1, x_2 \in S$ and $0 < \lambda < 1$ where $f(x_2) < f(x_1)$ we have $f((1-\lambda)\, x_1 + \lambda\, x_2) < f(x_1)$.

Figure A.2 illustrates a strictly quasiconvex function and contrasts it to a (strictly) convex function. Note that the strictly quasiconvex function does not have to be convex. The importance of such functions

PLACE FIGURE A.2 ABOUT HERE

follows from the following theorem (which is a generalization of the previous theorem.

Theorem If f(x) is a strictly quasiconvex function over the convex set S in (R^n), then any local optimal solution is a global optimal solution.



(Strictly) Convex Function

Strictly Quasiconvex Function

Figure A.2

NATIONAL POLITICAL ADAPTATION

IN A WORLD ENVIRONMENT: TOWARD

A SYSTEMS THEORY OF DYNAMIC POLITICAL PROCESSES

Stuart J. Thorson
Polimetrics Laboratory
Department of Political Science
The Ohio State University

Prepared for delivery at the 1972
annual meetings of the American
Association for the Advancement of Science
December 26-31, 1972

This is a slightly modified version of a paper presented to the 1972 Annual Meetings of the Society for General Systems Research, Mid-Atlantic States Division, Washington D.C. September 30, 1972.

Section I: Introduction

For quite some time now, biologists have used the concept of an "adaptive" system in explaining both macro and micro level biological changes. Very loosely, (and we will be more precise further on) an adaptive system is one which manages to change either itself or its environment in such a way as to "get along." Thus, for example, we are told that dinosaurs became extinct because they failed to adapt to their environment, whereas man is unique in his ability to adapt to a wide range of environments. More abstractly, biologists distinguish between organisms which adapt to a very specific environmental niche and those which achieve a more general level of adaptation. The niche adapted organism is very unlikely to survive if his environment is changed in the least bit, while the more generally adapted organism is able to tolerate fairly wide environmental changes.

Many social scientists have thought it might prove helpful to view social phenomena from the perspective of adaptive behavior. Recently several students of foreign policy have suggested that the biologist's conception of an adaptive system could be useful in analyzing foreign policy behaviors. That is, the hope seems to be in that there is some theory of adaptive biological systems, T_1, which has a model, M_1, which is isomorphic to a model, M_2, for a theory of national foreign behavior, T_2. If M_1 and M_2 are isomorphic, then by the law of deduction (Tarski, 1965:125) the existing of propositions of T_1 can be translated into propositions of T_2, the theory of foreign policy behavior. As an almost

trivial example, the sentence of T_1 (the biological theory) which read "A niche adapted organism whose environment is changed will fail to survive" might become in T_2 (the foreign policy theory) "A national system which has achieved a high degree of accurate foreign policy response of election for only a very specific international environment, will fail to survive in a changed international environment." As evidence for the proposition in T_1, the biologist might point to the rapidly disappearing Ridley turtle (whose nesting beaches are being altered) while as evidence for the proposition in T_2, the political scientist might look at the Greek city-states. This hope comes through fairly clearly in the work of several political scientists. For example, Rosenau (1967) sees the outstanding characteristic of adaptation theory as being its focus on the interaction between system and environment. "The subject matter of the foreign policy analyst is distinctive because his prime focus is the association between variations in the national actor and variations in its environment." Since 1967 Rosenau has done considerable work to develop his adaptation paradigm. McGowan (1970) has taken some of these notions and attempted to formalize them in a mathematical theory from which some of the consequences of adaptation theory can be examined empirically.

Perhaps the best way to explicate the Rosenau-McGowan approach is to quote at some length from McGowan (1970):

> In his most recent elaboration of the adaptation paradigm Rosenau argues as follows: First: 'considerable insight' can be gained from viewing national societies, like a cell or an organism, 'as entities that must adapt to their environ-

> ments to survive and prosper. That is, if an entity is to maintain the boundaries that separate it from other entities, it must act toward the other entities in such a way to keep its essential structures intact (Rosenau, 1970, p. 2).' *Second*, for national societies, 'adaptation means that fluctuations in the basic interaction patterns that sustain its social, economic, and political life must be kept within limits minimally acceptable to its members (Rosenau, 1970, p. 2).' *Third*, since there can be considerable disagreement over what are acceptable limits of variation in the performance of a society's economy or polity, the politics of national adaptation is infused with 'an intensity and drama unknown to other entities' and processes (Rosenau, 1970, p. 2). *Fourth*, the performance of essential societal structures is conditioned by external change, internal societal change, and the society's response to these two stimuli (Rosenau, 1970, p. 2). And *fifth*, given that any society's external environment is a basic source of variation in its essential structures, 'the need for foreign policy arises...out of the fact that the essential structures cannot be kept within acceptable limits unless some kind of behavior is undertaken toward the environment (Rosenau, 1970, p. 3).

As Rosenau has pointed out, there is interest in the interactions a national political actor and its environment; that is, with the nation and its international environment. In terms of the familiar black box diagram of Figure 1, it would look like this:

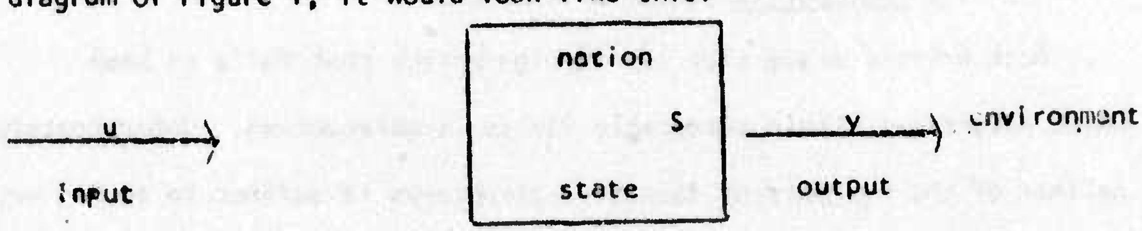


Figure 1

to have a system, however, more information must be provided than is contained in Figure 1. There must be a specification of the elements which comprise the system. In the case of a national political system, this

this is clearly no easy task and is one to which many social scientists have devoted much of their attention. Both Rosenau and McGowan recognize this problem and attempt to answer it by positing essential societal structures. Rosenau (1970) suggests four such structures:

(1) "...the patterns whereby the life and property of societies are preserved and protected..."

(2) "...the patterns whereby...their policy decisions (are) made and implemented..."

(3) "...the patterns whereby...their goals and services (are) acquired and distributed..."

(4) "...the patterns whereby...their members' cooperation (is) achieved and maintained..."

McGowan (1970) identifies five essential structures:

(1) The boundary of the society

(2) The society's economic system

(3) The polity of the society

(4) The culture of the society

(5) The integrative system of the society

Both writers argue that any foreign policy that fails to keep these structures within acceptable limits is maladaptive. Unfortunately, neither of the two sets of essential structures is defined in such a way that makes their measurement clear. Indeed, in McGowan's case the essential structures are analytic properties of any existing national system. Thus, as variables they are either present or not present, and if any are not present, the system by definition no longer "exists." A

foreign policy which results in any of the essential structures not being present is termed maladaptive. This of course is equivalent to saying that any foreign policy which results in the destruction of a nation-state is maladaptive.

There is nothing wrong with this from the vantage of general adaptation theory; however, from the standpoint of political theory McGowan's notion of acceptable limits is far too broad. For example, how should United States' involvement in Indochina be distinguished from her help in rebuilding Europe after World War II? The impacts of these two policies on the U.S. political system were very different; yet, in McGowan's sense, both are adaptive because neither resulted in the downfall of the United States. It would seem that any conception of the elements of the system ought be capable of reflecting these different impacts.

Rosenau is not so specific as McGowan on what ranges his essential structures can tolerate. He does suggest that the overall adaptation of a society can be measured by its least well adapted structure as well as how some of those structures might be measured. Rosenau argues that the structures can take on values over a fairly wide range. An example is the political structure. Here Rosenau focuses upon how much control a national system has over its own policies. As this control decreases, says Rosenau, so do the boundaries between the national and international systems begin to merge. Policies which result in decreasing this control are less adaptive than those which do not.

The problem with this sort of notion is that without carefully stating the "acceptable limits," it is impossible to label the results of a given policy "adaptive." For example, was the Egyptian reliance upon Soviet military assistance adaptive for Egypt or not?

Apart from the empirical problem of measurement and the conceptual problem of specifying limits, a further conceptual problem has arisen. In the preceding discussion "adaptive" has been used in two ways. First, mention was made of an adaptive political system. Second, certain foreign policy behaviors were said to be adaptive or maladaptive. Although at first glance these uses may appear the same, they are not. An adaptive system may at times behave maladaptively. This distinction will become more clear as some of the concepts of adaptation theory are defined more rigorously; for the present an example will have to suffice.

Some psychologists view learning as an adaptive process. That is, people learn in order to reduce certain basic drives (Hull, 1943). Learning, however, does not generally take place all at once; errors are made along the way. Some of these errors may, in fact, increase the drives rather than reduce them. In fact, no matter what limits are put on drive levels, there can always exist an error which might increase drives beyond these limits. That is, even though the learning system is conceptualized as being adaptive, it may still behave maladaptively.

The distinction just illustrated unfortunately does not seem to be consistently made by McGowan. Yet it is of importance to how the structures generating foreign policy are conceptualized. For it is

required that the foreign policies of a nation always be adaptive if the nation is to continue to exist (as McGowan seems to), something very much different is being said than simply to say foreign policy behaviors result from adaptive systems.

Already it seems the limits of the common sense vocabulary assocciated with adaptation theory have been reached. In order to go further the vocabulary must be developed more rigorously.

Taking the adaptation view seriously requires going beyond a simple common sense intuitive understanding of what is meant by the terms involved. A useful way of accomplishing this is to first introduce some basic systems concepts and then move to an explication of Simon's (1969) notion of an "artificial" system. As will be seen, the artificial system's framework fits in very nicely with Rosenau's emphasis upon the relation between the national actor and its environment.

Section II: Basic Systems Concepts

A government can be viewed as a system attempting to achieve goals in two linked environments--the government's national system and the international system. This view of government as a goal seeker immediately suggests some sort of cybernetic approach to the study of foreign policy. Great care, however, must be exercised in how cybernetics is applied to avoid concentrating upon a "conventional" sort of equilibrium ("equilibrium" will be defined more rigorously further on) and ignoring the dynamic characteristics of national adaptation.

The reason the adoption of a cybernetics approach so often leads to conventional equilibrium type analysis is that much of the work in cybernetics has dealt with what are known variously as negative feedback or deviation counteracting systems. The essential attribute of these systems is that, when disturbed, they behave in such a way as to minimize the effect of the disturbance. An example of a negative feedback system is the position that if you increase the income of lower class persons, they will only have more children and, as a result, their overall economic position will not be changed. The following directed signed graph illustrates this belief structure:

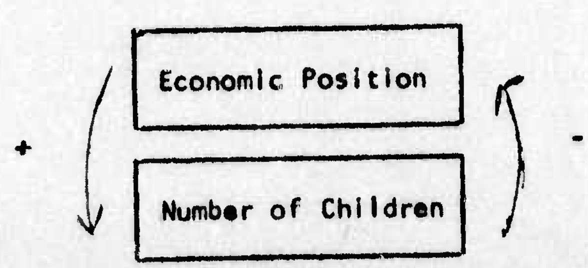


Figure 2

The positive arrow linking economic position with number of children indicates that an increase in a family's economic position will result in increasing the number of their children. The negative arrow designates that an increase in the number of children will decrease the overall economic position of the family. The arrow leading back to "economic position" has a minus sign, hence the name negative feedback system. Systems such as that in Figure 2 will generally tend toward an equilibrium state. The equilibrium values will depend upon the initial values and the size of the disturbance.

A graph such as Figure 2 may be termed a non-numerical structure. It is non-numerical in that the correspondence between the empirical referents (economic position and number of children) and the objects in the structure (the directed sign graph) preserve order relations but not magnitudes. Nothing is said about how _many_ more children should accompany an increase of _x_ dollars in income. It does, however, tell whether increasing income augments or inhibits the number of children in the family.

Even a casual glance at the cybernetics literature will reveal that much of the work is directed toward the analysis and design of highly sophisticated negative feedback mechanisms. In cybernetics, feedback is often used to indicate the discrepancy between the intended results and actual results of a given behavior. Generally the desire is to minimize the difference between intent and action and, as a result, an emphasis is placed upon the design of negative feedback systems.

Many aspects of social phenomenon, such as growth and patterned adaptive change, however, may often best be viewed as positive feedback mechanisms. The discussion by Coombs, et al. (1970) of the relation between the quality of faculty in an academic institution and the quality of graduate students in that institution is illustrative of this point. High quality faculty attracts high quality graduate students who in turn attract more high quality faculty. Or:

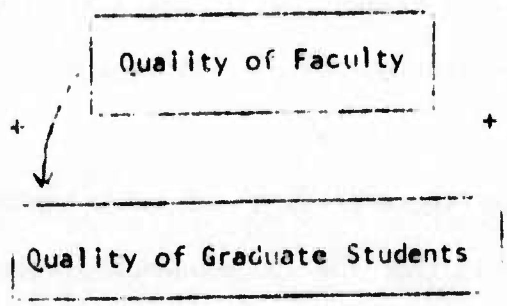


Figure 3

Figure 3 provides an example of a positive feedback structure. As can be seen, positive feedback loops augment initial disturbances.

Since the differences between positive and negative feedback systems are of some importance, it will be worthwhile to develop a numerical theory of the system shown in figure 2. For economic position (E) and number of children (C), the following difference equations can be written with the subscript referring to the time increment involved:

$$(1)\quad C_t \begin{cases} = C_{t-1} & \text{if and only if } E_{t-1} < E_{t-2} \\ = C_{t-1} + (E_{t-1} - E_{t-2}) & \text{if and only if } E_{t-1} \geq E_{t-2} \end{cases}$$

$$(2)\quad E_t = E_{t-1} - (C_{t-1} - C_{t-2})$$

Here equations (1) and (2) tell that increasing a family's economic position one unit at time t will result in increasing the number of their children by one at time t + 1. Table 1 shows the results for four time periods of a family which begins with no children and whose economic position goes from 1 at time 1 to t at time t.

Table 1

t	E	C
1	1	0
2	2	0
3	2	1
4	1	1
5	1	1

By time 4 the system has reached an equilibrium position of E = 1 and C = 1. Suppose now at time 6 a policy is instituted giving the family an increase in economic position to 3 (E = 3). Table 2 gives the results:

Table 2

t	E	C
6	3	1
7	3	3
8	1	3
9	1	3

The purpose of the example is not, of course, to claim that increasing a family's economic position by two units in one time period will result in their having twins the next period. Rather, the example was intended to demonstrate the over-time behavior exhibited by negative feedback systems and to show that attempts to look at political systems as negative feedback systems will often lead to viewing them in terms of their equilibrium positions.

The claim was made earlier that a government could be viewed as a component of an artificial system attempting to achieve goals in two linked environments. In order to explicate this, it will be necessary to discuss in some detail concepts such as system, goals, goal achievement, environments, and the ways in which environments can be linked. Once these concepts are well understood, a framework can be built from which to view political adaptation and change. At first, the discussion of empirically "empty" concepts may seem a rather sterile exercise; however, unless the basic structural and manipulative concepts are well in mind, the empirical interpretation which follows will be difficult, if not impossible, to evaluate.

A system may be defined as a set of objects together with the relations defined upon them. Thus a system is identical to a mathematical structure. The object is the basic building block of the system. Figure 2 describes a two object, two relation system. The objects are economic position (E) and number of children (C) and the relations are augmentation from E to C and inhibition from C to E. If the augmentation relation is denoted as R_+ and the inhibition relations as R_- the system (mathematical structure) of Figure 2 looks as follows:

$$S: \quad \langle E, C; ER_+C, CR_-E \rangle$$

Note the objects of S are listed first and then the relations obtaining between them.

Consider now a system described by equations (1) and (2):

$$S^*: \quad \langle E_t, C_t; ER^*_+C, CR^*_-E \rangle$$

The state of the system at a point in time is simply the value of each object in the system at that point. Thus from Table 2, the state of S* at time 6 is (E = 3, C = 1).

Most phenomena are not completely closed off from other phenomena; that is, there are interactions among phenomena. When a system is abstracted from such a phenomenon, it is generally called an open system, reflecting the fact that the system receives some sorts of inputs from the outside. Most all systems not only receive inputs, but they also have some way of sending outputs to the outside. This type of open system is the one depicted in the "black box" diagram of Figure 1. Here system S receives input u and sends output y. That which is external to the system is often called the system's **environment**.

A question of considerable interest to systems theorists is whether the system has an equilibrium point and, if it has, if the equilibrium is stable. A system state is said to be an equilibrium state if it is a state from which the system does not move unless it receives some external shock from its environment. Environmental shock here refers to some change in the environment which does not result from a change in the system. If a shock moves the system away from its equilibrium state and the system eventually moves back to equilibrium, then the equilibrium is said to be a stable one. A distinction is often made between two sorts of stability. The first is called asymptotic stability. Here if the shock does not move the system outside of some region about the equilibrium point, the system will return to equilibrium.

This region is referred to as the region of asymptotic stability. On the other hand, it may be that no matter where the system is moved, it will return to the equilibrium state. This property is called global stability. A system which is globably stable has its entire state space as a region of asymptotic stability.

Oftentimes because of measurement problems or a lack of conceptual precision it is impossible to determine whether or not a system is "really" in the same state. To help avoid these problems the definition of an equilibrium state can be relaxed by allowing each element a slight bit of variation resulting in a zone of equilibrium. Each state in this zone is not exactly the same as every other but they are, in a strictly defined sense, very close. As long as the system is in a state contained in this zone, it can be said to be in an equilibrium state.

An example might make this more clear. Imagine a system obstructed from a human being composed of his body temperature, pulse, and respiration rate. The system can then be thought of as a triple $\langle T, P, R\rangle$. A person whose temperature is 98.6, pulse is 100 beats per minute, and respiration rate is 15 breaths per minute can be represented by $\langle 98.6, 100, 15\rangle$. After making many observations it is noted that all three of these variables normally fluctuate a bit but tend to remain within certain limits. Suppose these limits are as follows:

Variables	Normal Range
T	97.0 - 99.4
P	85 - 115
R	12 - 18

By appropriately defining a zone of equilibrium, the system $\langle T, P, R \rangle$ can be said to be at equilibrium as long as each element is somewhere in its normal range.

After watching human beings a while longer, it might be decided to add a few more elements to the system: say blood pressure (B), output of the sweat glands (S), and behavioral activation level (A). If the states of this new system $\langle T, P, R, S, B, A \rangle$ were measured and recorded at closely spaced intervals and over a long period of time, it might be noted that whenever one of the variables moved outside of its normal limits, others would also move and the system would eventually return to equilibrium. Thus, for example, if the body temperature were to rise, the sweat glands might increase their output, cool off the body and the system would move back to its equilibrium region. In general, the system remains at equilibrium and the equilibrium is a stable one.

The sequence of outputs generated by a system is called its behavior. A goal or objective for a numerical system is a specification of the set of desired system states. In the example, a goal might be any system state where T is between 97.0 and 99.4, $85 \leq P \leq 115$, and $12 \leq R \leq 18$. The terms goal and objective will be used interchangeably.

It is important to recall that from the way system has been defined--a set of objects together with the relations defined upon them--it would be meaningless to talk about structureless systems. What is viewed as structure and what is not is, of course, dependent upon how the system of study is conceptualized. For example, Toda and Shuford (1965) ask: "When one cuts his finger with a knife, quite a number of tissue cells are ruined. Does this mean a change in the structure of this person?" The answer to their question is yes and no. If the objects of the person are said to be cells, then clearly there is a structure change. However, if the objects are more macroscopic body parts such as fingers, then cutting the finger simply changes the finger's state but does not change the structure of the system. A system is a mathematical structure and its elements and relations must be specified precisely if it is to be discussed meaningfully.

As will be shown, clear system specification is of crucial importance to anyone doing empirical comparative research. First, however, one more concept--that of a parameter--needs to be introduced at this point. Given a system, any element not included in it is a parameter. Some parameters may have no effect upon a system, others may have an effect only under certain conditions, and still others may have a very direct effect at all times. A more precise understanding of what is meant by a parameter should come from the example about to be presented.

Brunner (1970) provides a very nice discussion of some of the problems involved in doing comparative research when the systems involved are not well specified.

The theory used in this example will be one based upon Samuelson (1939). The objects in the system being theorized about are:

S_t = overall satisfaction level of the people in a given nation at time t

P_t = performance of the private sector of the nation at time t

G_t = performance of the government of the nation at time t

These objects (variables) can be related as follows:

$$(3) \quad P_t = \alpha S_{t-1}$$

$$(4) \quad G_t = B(P_t - P_{t-1})$$

$$(5) \quad S_t = P_t + G_t \qquad \text{where } \alpha \text{ and } B \geq 0$$

(3) states that private sector performance will be proportional to the preceding period's level of overall satisfaction. Equation (4) tells that government performance will be proportional to the change in private sector performance from this period to the preceding period. Finally, (5) is a simple accounting equation defining overall satisfaction to be the sum of government performance and private sector performance. Throughout this analysis it will be assumed that S, P, and G are measured in comparable units.

Figure 4 illustrates the structure of this set of equations. The single arrows signify no time advance and the double arrows indicate a time advance of one unit.

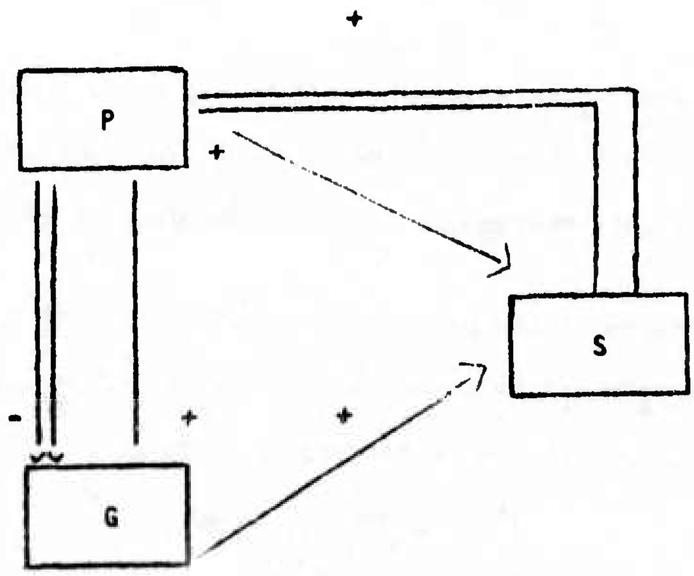


Figure 4

The state variables of the structure are G, P, and S and the relations among these state variables are depicted in Figure 4. The parameters which directly affect the structure of Figure 3 are $\propto$, B, and t. They are not included in the structural diagram of the equations.

Imagine four national systems (N_1, N_2, N_3, N_4) each of which is described by equations (3) - (5) but differ in their values of the parameters α and B. In N_1, α = .8; and B = 1.5; in N_2, α = .8 and B = 3.0; in N_3, α = .5 and B = 0; and in N_4, α = .5 and B = 1.0. The initial value (t = 1) of P and G is 0 in all four systems and the initial value (t = 1) of S is 1 in all the systems. Equations 3, 4, and 5 can be programmed on a computer and by substituting the appropriate values for and B, the states of each system for different values of t can be generated. Figure 5a shows the results of these runs.

As can be seen, each system exhibits very different behavior. The elements in N_3 and N_4 all go to an equilibrium state of $\langle 0, 0, 0 \rangle$

though those in N_3 approach it directly while those in N_4 oscillate to it. The elements of N_1 swing through increasing oscillations and those in N increase at a very rapid rate. These extremely diverse behaviors may be thought of as resulting from the same system. Would a political scientist analyzing the data in Figure 5 with conventional linear techniques recognize that each nation's behavior was generated by the same structure?

Brunner (1970) demonstrates very convincingly that the data analysis strategies presently employed by most political scientists (such as conventional regression analysis) will usually not reveal the underlying structure of the system. This will generally be the case whether the systems are analyzed cross-nationally at a point in time or individually as a time series. (See Brunner, 1970, pp. 6-7, for a more complete treatment of these data analysis problems.)

As considered thus far, this example illustrates several important problems facing political analysts. First, there is the very broad data analysis problem. To what extent can data--even time series data--be used to identify the basic structure of a model for a theory of national behavior? Since most analysis strategies cannot be used to distinguish between structure and parameters, it is the responsibility of the analyst to impose a basic structure on his observations prior to doing statistical manipulations. As Cain and Watts (1970, p. 229) point out, "Without a theoretical framework to provide order and a rationale for the large numbers of variables, we have no way of inter-

N_1

α = 0.800 β = 1.500

T	S(T)	P(T)	G(T)
1	1.000	0.000	0.000
2	2.000	0.800	1.200
3	2.800	1.600	1.200
4	3.200	2.240	0.960
5	3.040	2.560	0.480
6	2.240	2.432	-0.192
7	0.832	1.792	-0.960
8	-1.024	0.666	-1.690
9	-3.046	-0.819	-2.227
10	-4.864	-2.437	-2.427
11	-6.072	-3.891	-2.181
12	-6.308	-4.858	-1.450
13	-5.329	-5.046	-0.283
14	-3.088	-4.263	1.175
15	0.218	-2.471	2.689
16	4.142	0.174	3.968
17	8.022	3.314	4.709
18	11.074	6.418	4.656
19	12.755	8.859	3.662
20	11.755	10.017	1.737

N_2

α = 0.800 β = 3.000

T	S(T)	P(T)	G(T)
1	1.000	0.000	0.000
2	3.200	0.800	2.400
3	7.840	2.560	5.280
4	17.408	6.272	11.136
5	36.890	13.926	22.963
6	76.267	29.512	46.756
7	155.521	61.014	94.507
8	314.625	124.417	190.208
9	633.549	251.700	381.849

N_3

α = 0.500 β = 0.000

T	S(T)	P(T)	G(T)
1	1.000	0.000	0.000
2	0.500	0.500	0.000
3	0.250	0.250	0.000
4	0.125	0.125	0.000
5	0.062	0.062	0.000
6	0.031	0.031	0.000
7	0.016	0.016	0.000
8	0.008	0.008	0.000
9	0.004	0.004	0.000
10	0.002	0.002	0.000
11	0.001	0.001	0.000
12	0.000	0.000	0.000
13	0.000	0.000	0.000

N_4

α = 0.500 β = 1.000

T	S(T)	P(T)	G(T)
1	1.000	0.000	0.000
2	1.000	0.500	0.500
3	0.500	0.500	0.000
4	0.000	0.250	-0.250
5	-0.250	0.000	-0.250
6	-0.250	-0.125	-0.125
7	-0.125	-0.125	0.000
8	-0.000	-0.062	0.062
9	0.062	0.000	0.062
10	0.062	0.031	0.031
11	0.031	0.031	0.000
12	0.000	0.016	-0.016
13	-0.016	0.000	-0.016
14	-0.016	-0.008	-0.008
15	-0.008	-0.008	0.000
16	-0.000	-0.004	0.004
17	-0.004	0.000	0.004
18	0.004	0.002	0.002
19	0.002	0.002	0.000
20	0.000	0.001	-0.001
21	-0.001	0.000	-0.001
22	-0.001	0.000	0.000
23	0.000	0.000	0.000
24	0.000	0.000	0.000

Figure 5a

N_1

$\alpha = 0.800$ $\beta = 1.500$

T	S(T)	P(T)	G(T)
1	1.000	0.000	0.000
2	0.800	0.800	1.200
3	0.640	0.640	-0.240
4	0.512	0.512	-0.192
5	0.410	0.410	-0.154
6	0.328	0.328	-0.123
7	0.262	0.262	-0.098
8	0.210	0.210	-0.079
9	0.168	0.168	-0.063
10	0.134	0.134	-0.050
.	.	.	.
.	.	.	.
.	.	.	.
34	0.001	0.001	0.000
35	0.001	0.001	0.000
36	0.000	0.000	0.000
37	0.000	0.000	0.000

N_2

$\alpha = 0.800$ $\beta = 3.000$

T	S(T)	P(T)	G(T)
1	1.000	0.000	0.000
2	0.800	0.800	2.400
3	0.640	0.640	-0.480
4	0.512	0.512	-0.384
5	0.410	0.410	-0.307
6	0.328	0.328	-0.246
7	0.262	0.262	-0.197
8	0.210	0.210	-0.157
9	0.168	0.168	-0.126
10	0.134	0.134	-0.101
.	.	.	.
.	.	.	.
.	.	.	.
34	0.001	0.001	0.000
35	0.001	0.001	0.000
36	0.000	0.000	0.000
37	0.000	0.000	0.000

N_3

$\alpha = 0.500$ $\beta = 0.000$

T	S(T)	P(T)	G(T)
1	1.000	0.000	0.000
2	0.500	0.500	0.000
3	0.250	0.250	0.000
4	0.125	0.125	0.000
5	0.062	0.062	0.000
6	0.031	0.031	0.000
7	0.016	0.016	0.000
8	0.008	0.008	0.000
9	0.004	0.004	0.000
10	0.002	0.002	0.000
11	0.001	0.001	0.000
12	0.000	0.000	0.000
13	0.000	0.000	0.000
14	0.000	0.000	0.000

N_4

$\alpha = 0.500$ $\beta = 1.000$

T	S(T)	P(T)	G(T)
1	1.000	0.000	0.000
2	0.500	0.500	0.500
3	0.250	0.250	-0.250
4	0.125	0.125	-0.125
5	0.062	0.062	-0.062
6	0.031	0.031	-0.031
7	0.016	0.016	-0.016
8	0.008	0.008	-0.008
9	0.004	0.004	-0.004
10	0.002	0.002	-0.002
11	0.001	0.001	-0.001
12	0.000	0.000	0.000
13	0.000	0.000	0.000
14	0.000	0.000	0.000

Figure 5b

preting the statistical results." Regression analysis is properly used to estimate population parameters only when the structure of the model elements are already specified. This specification of structure must precede the application of parameter estimation techniques.

A second problem is the very subtle distinction between structural differences and state differences. The various behaviors of the four imaginary nations all resulted from the same basic structure. In positing systems it is this structure which must be isolated, and, in doing so, care must be exercised not to assume fallaciously that because two nations pass through very different states (e.g., exhibit very different behaviors) they must be modeled by different structures. It may, of course, be that different structures are appropriate, but this will not necessarily be the case.

With the structure of Figure 4 and the parameter values specified in Figure 5, it has been shown that the same structure can result in very different over-time behavior. Suppose now the theory is changed by making equation (5) read:

$$(5') \quad S_t = P_t$$

Equation (5') asserts that overall satisfaction will simply be equal to private sector performance and that the government performance has no effect upon satisfaction. The result of this structural change is to push the four elements of N_1, N_2, N_3, and N_4 to an equilibrium position of $\langle 0, 0, 0 \rangle$. The over-time behaviors of each of these systems can be seen in Figure 5b. Though all four systems end up in

the same state, their behavior paths in getting there are again different. In this case, the theory change did not affect the equilibrium positions of N_3, and N_4, even though it did affect the sequence of states N_4 passed through in getting to equilibrium. Changing the theory with equation (5') demonstrates how inadequate a characterization of system behavior is the conventional concept of equilibrium. Simply knowing that two systems have the same equilibrium point gives very little information about whether they are isomorphic. N_3, it will be recalled, behaved exactly the same before and after the structure change. The systems in Figure 5a were isomorphic yet two went to equilibrium and two did not.

Further, interest will often be centered upon what states a system passes through in getting to equilibrium. A given policy (sequence of outputs of the I.E.), for example, which would move the overall system to a desired equilibrium point might be rejected if it was known that getting to that point entailed the system's going through some highly undesirable states. Specifically, while equations (5) and (5') will be behaviorally indistinguishable when G (or μ) is equal to zero, very different policies will be recommended if the level of satisfaction is a function of the government's performance (although observed government performance is equal to zero) than if satisfaction is unrelated to government performance.

Section III: Artificial Systems and Adaptive Systems

Having defined a system, it is possible to move to a discussion of a specific sub-class of systems--artificial systems. While the distinction between "artificial" and "natural" systems is not always clear, the basic idea is that artificial systems are directed to human goals whereas natural ones may not be. Simon (1969, pp. 5, 6) suggests four criteria for separating the artificial from the natural:

> "1. Artificial things are synthesized (though not always or usually with full forethought) by man.
>
> 2. Artificial things may imitate appearances in natural things while lacking, in one or many respects, the reality of the latter.
>
> 3. Artificial things may be characterized in terms of functions, goals, adaptation.
>
> 4. Artificial things are often discussed, particularly when they are being designed, in terms of imperatives as well as descriptives."

Thus, for example, a forest would be a natural system while a farm would be an artificial system.

We can talk about artificial systems as having an inner environment (I.E.) attempting to achieve some goal(s) in an outer environment (O.E.). The hookup between the I.E. and the O.E. is called the interface. Bailey and Holt (1971) break the interface into two parts and put the I.E. and O.E. into a control theoretic structure as in the following figure:

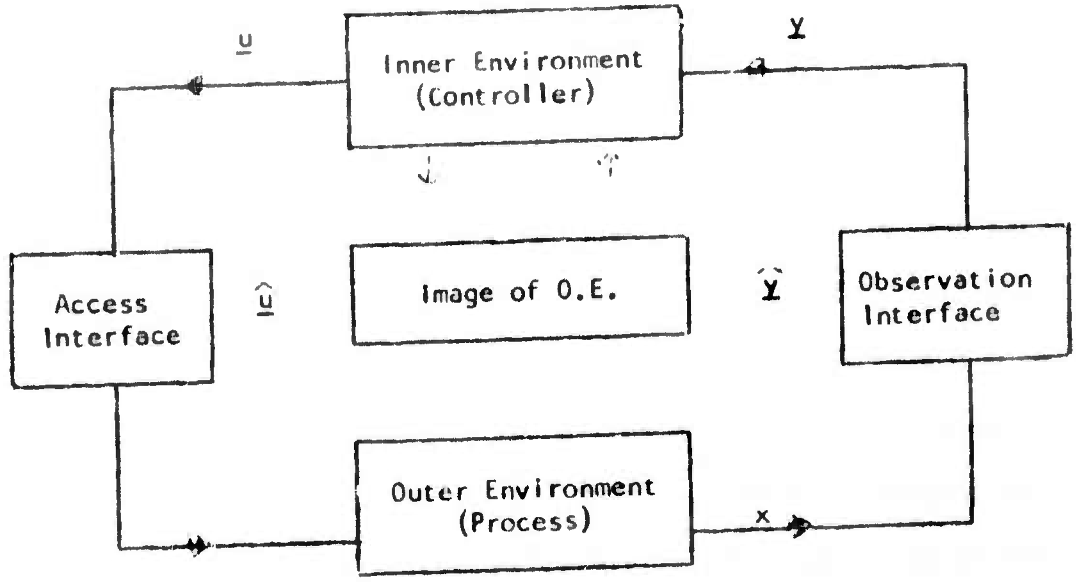


Figure 6

Figure 6 is very general, but does illustrate the additional structure common to all artificial systems.

The easiest way to describe the scope of this diagram is through a very simple example. Let the inner environment (I.E.) be a country's government and the outer environment (O.E.) be the economic system of that country. Suppose further that the government's goal is to remain in power and that it "believes" it can do so only by keeping the economic system in a certain specified set of acceptable states. The state of the O.E. is represented by the vector $\underline{x}$ and might include such things as each citizen's income, all sales transactions, and other such elements.

The government must have some way of observing $\underline{x}$ so that it can know whether the economy is in an acceptable state and yet it could not observe each and every sales transaction, etc. directly nor, even if it

could get it, would it be able to process the information. The problem of observing the O.E. is represented in Figure 6 by the observation interface. The observation interface may be thought of as the I.E.'s sensing device in the O.E. In the case of our example, the government might set up various agencies to collect economic data. Since, in this example, $\underline{x}$ would contain way too much information, the I.E. incorporates into the observation interface an indicator system. Thus instead of having $\underline{x}$ as an input, the I.E. receives $\underline{y}$. The vector $\underline{y}$ might include such indicators as GNP and unemployment rates. In some cases $\underline{y}$ and $\underline{x}$ will be equivalent. Most often, however, this will not be the case and it is important that the notation reflect this possible distinction.

Upon receiving $\underline{y}$, the I.E. must evaluate it to determine what sort of policy is indicated. This evaluation may be thought of as taking place in the I.E.'s image of the O.E. In our example the image might consist of a Walrasian equilibrium model of the economy. Generally, this image will, at least in part, contain the elements of $\underline{y}$. In this way $\underline{y}$ can be used to set the "state" of the image and various policy alternatives ($\underline{\ddot{u}}$) can be put into the image to assess their differential impacts ($\underline{\ddot{y}}$). Generally the $\underline{\ddot{u}}$ producing the most desired $\underline{\ddot{y}}$ value will be chosen as the value of $\underline{u}$ to send into the O.E. The elements of the $\underline{u}$ vector, to have any impact, must have some way of getting into the O.E.; that is, the I.E. must have some access interface which is capable of implementing $\underline{u}$ in the O.E. Fiscal and monetary policy serve as accesses for the government in the example we

have been discussing. The preceding rather crude illustration suggests the high degree of inter-relation between the various elements--goals, I.E., O.E., image, and interfaces--of artificial systems.

With these concepts it is possible to explicate what is meant by an adaptive system. Before proceeding to the definition, however, it should be made clear that there is no "generally accepted" definition of an adaptive system. Indeed there are many competing definitions which are inconsistent with each other. This fact does not imply that most or even some of these definitions are "wrong." It simply means that no definition has been put forward which was so persuasive as to induce the abandonment of all other competing definitions.

An adaptive system can be defined as any system which generates outputs in such a way as to seek to maintain state variables within certain limits. Adaptive systems are goal-seeking systems. The goal is expressed in terms of desired values of state variables. Such systems may or may not have equilibrium states. In investigating adaptive systems, the analyst is concerned with the goals of the system; how, if at all, goals can be modified; how outputs are judged as successes or failures; the mechanism through which information about the environment and past system states is transformed into outputs; and other such questions.

Murphy (1965) has identified several properties of all adaptive systems whether they be social, biological, physical, or engineering:

(1) At any point in time the system can move off in any one of a number of directions.

(2) Any of these moves will be followed by a change in the system and perhaps in the environment. These changes become a part of the historical record of the system.

(3) Every adaptive system must have some sort of decision-making function. On the basis of the historical record and an evaluation of the effect of each action on the present and future states of the system, the decision-making function chooses one of the alternative actions.

(4) Following the taking of an action, the system may or may not achieve the anticipated results. Uncertainties in the environment or the effect of the action may cause the system to move in a direction which was unintended.

(5) If the result was unfortunate, there is no recourse. The only corrective measure is to reestablish the above sequence of events all over again.

Clearly, then a simple "black box" system is not enough to illustrate an adaptive system. Several components must be in the black box before it can be labeled adaptive. First, the system must have contained some sort of internal clock so that it can sort out and act upon inputs coming at various times. This clock may not be the familiar sidereal one measuring time continuously and in constant intervals. The 'time' measured by the clock is an important problem. For if the dynamic aspects of adaptive (ormal-adaptive) change are to be studied, the analyst must have in mind a well-understood view of time.

The analysis of time presented here will follow very closely that of T. Windeknecht (1971). At first this may appear needlessly abstract. Hopefully, however, the abstraction will prove of help in examining political adaptation and change.

A set T together with a function + which maps the cartesian product T x T into T $[T \times T \to T]$ which satisfies the associative axiom:

$$t + (t' + t'') = (t + t') + t''$$

for all t, t', t'' belonging to T is known as a <u>semigroup</u>. A semigroup with an element 0 belonging to T such that:

$$t + 0 = 0 + t$$

for all t belonging to T is a <u>monoid</u>.

Given a monoid T, left division over T is the relation on T such that:

$$t \leq t' \Longleftrightarrow \exists(t'') : t'' \neq 0 \wedge t' = t + t'' \quad (t'' \in T)$$

where:

$$\Longleftrightarrow \; \equiv \text{"if and only if"}$$

$$\exists (x) \equiv \text{"There exists an X such that"}$$

$$\wedge \equiv \text{"and"}$$

$$\in \equiv \text{belongs to}$$

The left division relation asserts a simple ordering over the elements of T.

A <u>time set</u> is then defined as a monoid T with the following three properties:

(i) $(\exists t_1)(\exists t_2) : (t_1 = 0 \vee t_2 = 0) \wedge t_1 + t = t' + t_2 \quad (t_1, t_2 \in T)$

(ii) $t_1 + t = t + t_2 \Longleftrightarrow t_1 = t_2$

(iii) $t_1 + t = 0 \Longrightarrow t_1 = 0$

where

$$\vee \equiv \text{"or"}$$

$$\Longrightarrow \; \equiv \text{"implies"}$$

Two sets which meet the definition of a time set are the set of nonnegative real numbers (e.g., 1, 2.5, 3.4) and the set of nonnegative integers (e.g., 1, 2, 3,...). In both cases the identity element is 0 and the left division relation is that of less than (<) on the positive numbers.

Why, it might be asked, is there a need to be so formal and abstract in talking about time; after all, does not everyone know what time is? There are several reasons for taking a formal approach. First, as may have been noticed, a time set is a system. Examples have already been given of problems which can arise when the elements and relations of a system are not carefully defined. Since time is such an important concept, care must be exercised not to fall unknowingly into traps simply by being careless in defining time. Second, work by Arbib (1966) and Bailey and Holt (1971) suggests that control theory and automata theory are to work together in the same structure, time must be viewed as an ordered monoid rather than an ordered group. (for an example, see Windeknecht, (1971), p. 61.)

Further, looking at time abstractly enables getting outside of the idea of time necessarily being measured in seconds, minutes, hours, days, years, and other such units. The way time has been defined here, it is essentailly an ordering concept in that it gives a way to "tag" different observations in a meaningful way. Albert Einstein wrote of time (quoted in Barnett (1948, p. 47, 63): "The experiences of an individual appear to us arranged in a series of events; in this series

the single events which we remember appear to be ordered according to the criterion of 'earlier' and 'later'. There exists, therefore, for the individual, an I-time, or subjective time. This in itself is not measurable. I (Einstein) can, indeed, associate numbers with events, in such a way that a greater number is associated with the later event than with an earlier one. This association I can define by means of a clock by comparing the order of events furnished by the clock with the order of the given series of events. We understand by a clock something which provides a series of events which can be counted...every reference body (or coordinate system) has its own particular time; unless we are told the reference body to which the statement of time refers, there is no meaning in a statement of the time of an event." Earlier, Gunn (1929) argued that a major problem in physics was the confusion between physical time, mathematical time, and clock time. More recently, Ornstein (1969) claims that modern psychology has been held back by confusing experential time, clock time and biological time.

A problem for the student of politics is to develop a concept of time which is, in some as yet not well-defined sense, consistent with the phenomenon he is studying. It must be emphasized that there is no a priori reason why this conception should be the everyday calendar time generally used by political scientists. Several examples may help to illustrate this point. In the United States elections for the House of Representatives are held every two years. Great Britain, on the other hand, elects its House of Commons at least every five years or

whenever it is dissolved by the Prime Minister. If the presence or absence of U.S. Congressional elections and British Parliamentary elections were plotted against calendar time, it might be concluded that in the U.S. elections are held very regularly while in Britain they are not. This conclusion would be warranted if by "regular" was meant something like "evenly spaced in calendar time." For the purpose of doing comparative research, however, this may not be a desirable sense "of" "regular" to use. Instead regular might be used in a more general manner to mean "evenly spaced in a system with reference to that system's clock."

This formal analysis of time served to suggest the minimum structure thought to be necessary to a time concept. A question which requires much additional thought is that of how to add substance to this structure in such a way as to have a time concept which seems to tie in with political phenomena. This is especially important in making inferences to the structures of the models of nations from observations on variables ordered by calendar time. An explicit conception of time must be an aspect of the theory which suggested the observations or else there will be no appropriate means of ordering these observations.

Independent of the specific conception of time which is eventually adopted, a dynamic system can be defined as one which is directly parameterized by time. The government 'satisfaction' theory discussed earlier is an example of a dynamic system. By "directly parameterized" it is roughly meant that the value of the time parameter affects directly the values of the system elements.

If, as was suggested earlier, many social processes are growth processes best modeled by positive feedback systems, then this together with a concept of time suggests that the kinds of stability notions which have been so useful in analyzing dynamic physical systems may have very limited applications in the study of the dynamics of political adaptation. The best known example of a stable dynamic physical system is a marble in a bowl. When perturbed (within certain limits) the marble will return to its position at the bottom of the bowl. However, political systems may well not be best studied in terms of this notion of "point stability." What may be required is a higher order notion of stability. A biologist, C. H. Waddington, (1957, p. 32) has suggested the concept of chreod to refer to a trajectory in a system's state space which acts as an attractor to other trajectories. The notion of chreod may be illustrated as follows.

Imagine a large area of land containing several rivers and having all the land belonging to one or another river basin. This arrangement is shown in Figure 7. The idea of a river basin entails that water falling into basin 1 will, in most cases, eventually end up in river 1 and so on for basins and rivers 2 and 3. Once the water gets into a given river bed it will flow the path of the river. The only way for water from one basin to get into the river of another is through some unusual outside force such as its being carried in a pail or diverted through a canal. For water in basin 1, river bed 1 is a chreod. River beds 2 and 3 are chreods for water in river basins 2 and 3.

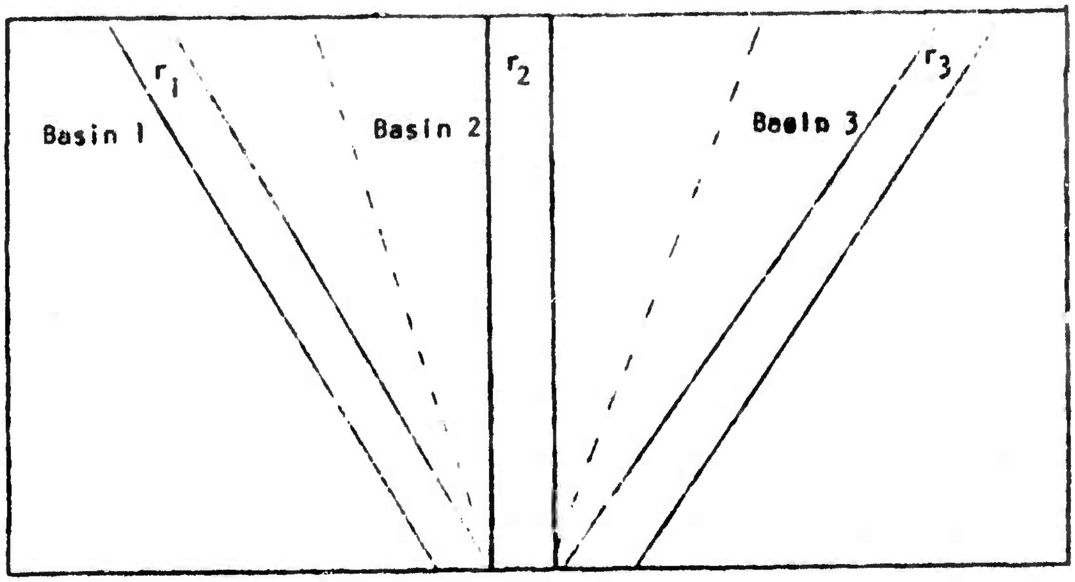


Figure 7

In a loose sense, a chreod is a higher order stability wherein it is the path about which the system is stable rather than a specific point. Chreods are essentially "developmental pathways" for the system of study. Most of the formal work which has been done in this area is by the French topologist Rene Thom. Thom (1968, 1970) sees as a fundamental problem the explanation of the stability of a temporal (i.e., dynamic) structure in terms of the organization of that structure. This problem can often be resolved by describing the process by a chreod.

Certainly Thom's problem is an important one for the political scientist. How can the stability of a dynamic political system be explained in terms of the organization of the structure of the model of that system. Note here that stability means correspondence to the chreod and not lack of violence or point stability.

Let us now return to the second of Murphy's requirements for an adaptive system; that is, the system must have some kind of memory. This is necessary if the system is to act, in part, on the basis of its historical record. Implied by this is Ashby's requirement that all adaptive systems be feedback systems. Third, the adaptive system must have a decision rule which can evaluate the past performance and the present state to choose among alternative behaviors. Fourth, it must have some sort of goal or objective. The goal may be viewed as setting and retaining state variables within certain limits.

Hopefully, the notion of an adaptive system is now clear enough to allow examining how this structure might be generalized to be relevant to the study of foreign policy.

Section IV: Adaptative Systems and Foreign Policy

Indeed it has already been pointed out that the notion of adaptation is not at all new in political analysis. Its emphasis upon goal-seeking systems meshes nicely with intuitive feelings about political actors. Politicians behave in a manner which is designed to help them to meet their goals. Certainly there is no obvious reason a nation's behavior cannot be looked at in an analogous fashion. Hanrieder (1967) defines foreign policy as "...the more or less coordinated strategy with which institutionally designated decision-makers seek to manipulate the international environment." Unless the argument is made that these foreign policy manipulations are made willy-nilly and without intended direction, it must be that they are aimed at reaching some goal.

Clearly if adaptation theory is to be interpreted as an empirical theory of foreign policy behavior, the problem of specifying acceptable limits on measureable state variables must be resolved. However, without doing this it is still possible to make some qualitative statements about how various sorts of adaptive systems might respond to certain kinds of environmental changes by building upon the artificial systems framework developed earlier. To do this, these constructs must be interpreted in a way helpful to the student of politics. For example, it is not very enlightening to simply relabel an I.E. as the government unless there exists an appropriate vocabulary with which to discuss governments. "Appropriate" here refers to the necessity for the

vocabulary to fit with both social science results and the artificial systems framework.

A goal or objective has already been defined to be a set of desired system states. Without getting into the empirical problems associated with trying to determine the goals of any particular nation, it is still possible to make some general statements about how goals may be viewed from the vantage of artificial systems.

In designing policies (sequences of 'u's) to achieve goals in the O.E., the responsible decision-making components of the I.E. must, in their image of the O.E., categorize the variables and parameters of the O.E. as to whether they are manipulable or non-manipulable and whether they are exogenous or endogenous:

1. Manipulable variables are those whose values are directly controllable by the given I.E. decision component.

2. Non-Manipulable variables may vary by functions of other variables in the models but not directly controllable by I.E. decision component actions.

3. Exogenous variables affect but are not directly affected by the other variables in the O.E.

4. Endogenous variables are those which may affect other variables and are affected by other variables in the system.

In conceptualizing these distinctions, the following classification table may be helpful. Endogenous-manipulable variables cannot exist since, by definition, endogenous variables can only be affected through exogenous ones.

Table 3

	Manipulable	Non-Manipulable
Exogenous	Generally the Policy Variables	?
Endogenous	None	Often Used as Performance Measures

It is important that the policy-maker be aware of which O.E. variables he is able to directly manipulate through his policy choices and which he is not. Yet this distinction is generally overlooked by behavioral scientists rushing to "explain" large percentages of variance with very few variables. In constructing theories of the O.E., decisions must be made as to which variables ought be included in the theory and which ought be excluded. These decisions, in turn, suggest devising measures of variable "significance."

If the objective of a particular theory is to parsimoniously describe the "behavior" of the O.E., then a criterion for including or excluding a given variable such as "proportion of variance explained" makes perfectly good sense (assuming, of course, there are independent

reasons to believe the underlying structure has been identified) as a way of isolating "significant" variables. However, if a goal of the theory is to enable its user to somehow change the behavior of the O.E., the import of an inclusion criterion such as "percent of variance explained" may be greatly reduced. It would be as if an eggregiously overweight person were told by his doctor that a carefully done empirical study of body weight showed that height and age are only "significant" correlates of body weight. Based on this "theory," it is unlikely that anything can be done about his overweight problem (short of perhaps cutting him off at the knee or adding several feet of leg. (For a more extended treatment of this topic, see Kanter and Thorson (1972).

Not all variables are equally susceptible to manipulation by every component of the O.E. One's relation to the policy process will have an important effect on partitioning variables according to manipulability. The proverbial New York taxi driver may well understand which actions will influence the arms races, but, for people in his position, few if any variables are manipulable. Presumably, from the perspective of the President, a somewhat larger number of variables are controllable. Since which variables are "important" in a 'policy' theory depend in part on which variables are manipulable, the designer of 'policy' theory should be sensitive to the position of the theory's consumer. The theory for providing advice to the President will be "significantly" different from the theory which yields responses appropriate to taxi drivers.

A given component of the I.E. (i.e., "the government," or that portion of the government which makes foreign policy decisions) in selecting foreign policy alternatives can be viewed as facing decision problems with the following elements (adapted from Ackoff, 1962):

C_i = an n element vector of manipulable variables

U = a set of values for the non-manipulable values

$f(C_i;U)$ = the image of the O.E.; a set of functional relations between the elements of the O.E.

V_i = the value to the decision maker of implementing alternative i

P_i = m element vector of performance measures affected by implementation of policy alternative i

$g(P_i)$ = objective function transforming m-performance measures into (ideally) a scalar to be maximized or minimized

X_i = j-element vector of policy alternatives, x

With this notation, the following functions can be written:

$$V_i = g(P_i)$$

$$P_i = f(C_i;U)$$

Moreover, the decision problem facing the particular component of the I.E. can be defined. Constraints--be they political, physical, fiscal, etc.--rule out some policy alternatives as infeasible. Therefore, only the reduced set of feasible alternatives X^f need be considered. An optimal policy, $\hat{x}$, can then be defined as one which satisfies the following function (Mesarovic, 1970 and Richardson and Pelsoci, 1971):

$$(\forall x)_{x^f} \quad g(P_{\hat{i}})Rg(P)$$

where R is generally a relation such as $\geq$ or $\leq$. As an illustration, suppose the goal is to minimize $g(P_i)$. The I.E. component would then want to select a policy alternative $\hat{x}_i^f$ from x^f such that $g(P_{\hat{i}})$ is less than or equal to $g(P)$ for any other x_i.

Oftentimes it is extremely difficult to quantify the elements of P_i. For example, suppose the elements of P_i include political stability, economic development, and attitudes toward the U.S. government. From a policy makers perspective, the temptation here is to take the element most easily quantified (in this case probably economic development) and attempt to maximize (minimize) it with the hope the others will follow along. Thus the motto "hard data drive out soft." Oftentimes, however, yielding to this temptation can have disastrous long-term consequences in the case where, over some interval, increases in economic development lead to a decrease in stability which in turn encourages hostility toward the U.S. A policy maker who simply optimized on economic development might soon be confronted with a rapidly deteriorating situation.

Once P_i, C_i, and $f(C_i,U)$ are developed, the problem becomes one of defining the objective function $g(P_i)$. In classical optimization problems, $g(P_i)$ maps P_i (an m-element vector) into a single value (a scalar). In many economic applications, for example, $g(P)$ is simply the sum of the dollar cost of the components of P_i and the goal is to minimize $g(P)$ thereby minimizing total cost. However in many political applications there does not seem to exist a single dimension into which the elements

of P_i can be mapped. For example, there is no clear way to add dollars and political prestige. Therefore, instead of facing a scalar optimization problem, the political policy maker often faces what has been termed a vector maximization problem (Geoffrian, 1968). Satisfactory analytical solutions to most varieties of vector optimization problems are still non-existant.

Another aspect of the I.F. decision problem can best be viewed in terms of the concepts developed by Mesarovic, Macko, and Takahara (1970). One of their concerns is with the designing of controllers for coupled subsystems. Coupled subsystems may be thought of as those in which changes in one subsystem may force changes in the other subsystem. The subsystems are in some way linked. If the O.E. of a government is seen as everything external to the government, then two subsystems of the O.E. might be the domestic subsystem and the international subsystem. Since changes in one can, under certain conditions, generate changes in the other, the two subsystems are coupled. A precise definition of coupling can be given in terms of properties of the matrices of coefficients of the subsystems, but in the context of this discussion, little if anything would be gained by such precision. Simon and Ando (1961) provide an interesting formal analysis of some aspects of coupling for those who would like a more rigorous approach.

Suppose, for illustration, that the O.E. is decomposed into an international and a domestic subsystem as in Figure 8.

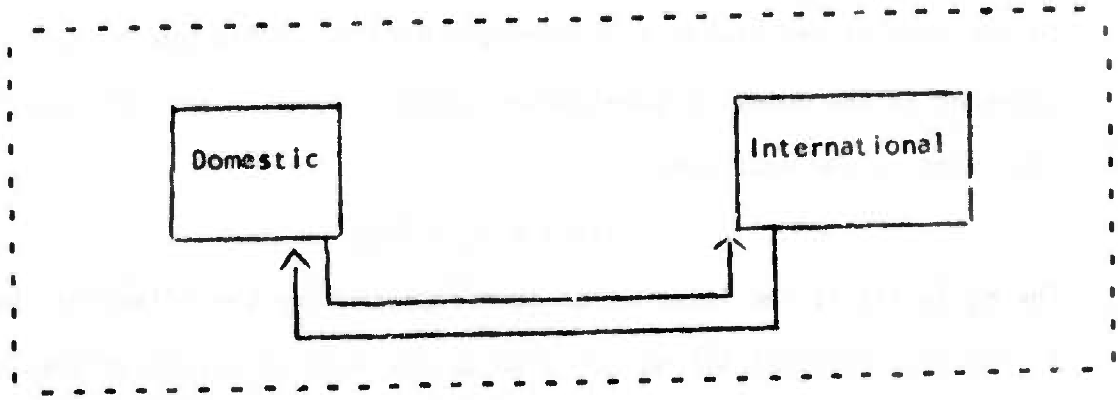


Figure 8

The O.E. is enclosed by dotted lines, and the lines connecting the two subsystems represent the coupling. In designing an I.E. structure to achieve goals in this O.E., it is likely that, since international problems are generally rather different than domestic ones, two "organizations" would be built into the I.E. These "organizations" might be the Ministry of Domestic Affairs and the Ministry of Foreign Affairs. Suppose further that the only way either Ministry can affect the subsystem it is concerned with is by spending political power units. Lastly, ignoring the interface problem by assuming there is no interface problem and that $\underline{y}$ is observed directly and accurately), results in what is pictured in Figure 9.

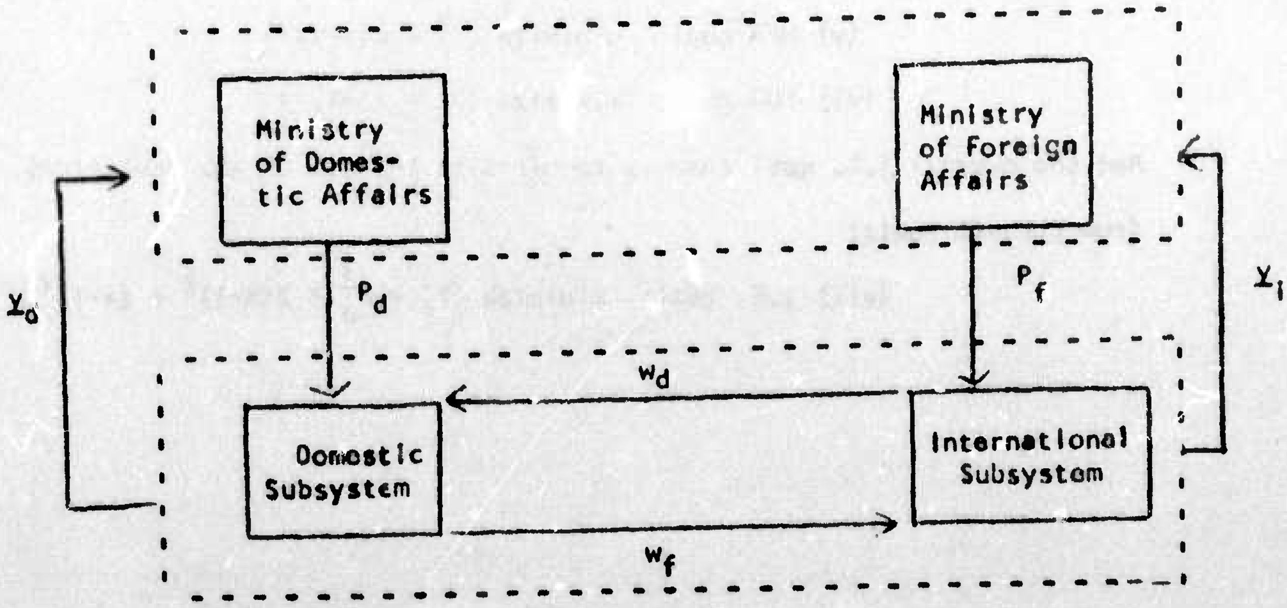


Figure 9

In the case of the Ministry of Domestic Affairs (MDA), power units (P_d) expended in the domestic sub-system increase domestic satisfaction (S) according to the equation:

$$\text{(i)}\quad S = P_d - 2W_d.$$

The W_d in (i) is the interaction term representing the effect of changes in the international sub-system upon S. It will be specified further in equation (iii). The Ministry of Foreign Affairs (MFA) exchanges its power units (P_f) for national defense (K) according to the following:

$$\text{(ii)}\quad K = 2P_f - W_f$$

Again, W_f represents how changes in the international sub-system affect the domestic sub-system. These interactions are:

$$\text{(iii)}\quad W_d = S - 1/2P_s$$

$$\text{(iv)}\quad W_f = K - 1/2P_f$$

Suppose the goal of the I.E. to move the O.E. to where K = 1 and S = 1. If K or S is smaller than 1, it greatly increases the likelihood the government will fall out of power while values greater than 1 would signify a weste of power units. With this goal in mind, the sub-goals for the MDA and MFA would look as follows:

$$\text{(v) MFA goal:}\quad \text{minimize } (P_f^2 + 2(K-1)^2)$$

$$\text{(vi) MDA goal:}\quad \text{minimize } (P_d^2 + (S-1)^2)$$

And the overall I.E. goal then is to minimize the sum of the deviations from the sub-goals:

$$\text{(vii) I.E. goal:}\quad \text{minimize } (P_f^2 + P_d^2 + 2(K-1)^2 + (S-1)^2)$$

Suppose now the I.E.'s image of the O.E. ignores the coupling and assumes contrary to equations (i) and (ii) that the international and domestic processes are completely uncoupled, that is,

$$(i')\ S = P_d \text{ and,}$$

$$(ii')\ K = 2P_f$$

If the image is that described by (i') and (ii') above, then it can be shown that the values of P_d and P_f which best approach the sub-goal with a minimum expenditure are $P_d = 1/2$ and $P_f = 4/9$. When put into equation (vii) (which may be thought of as an overall performance evaluation function), these values of P_d and P_f produce a value for (vii) of 4.09.

An important question then is, how much does ignoring the coupling cost the I.E.? It is at this point that the work of Mesarovic, *et al.* becomes relevant. They demonstrate that by putting a controller over the MDA and the MFA as in Figure 8 and by taking into account the coupling this super-controller can, through proper coordination of the MDA and the MFA, increase the overall performance of the I.E. from 4.09 to .088 (where the lower the score the better the performance).

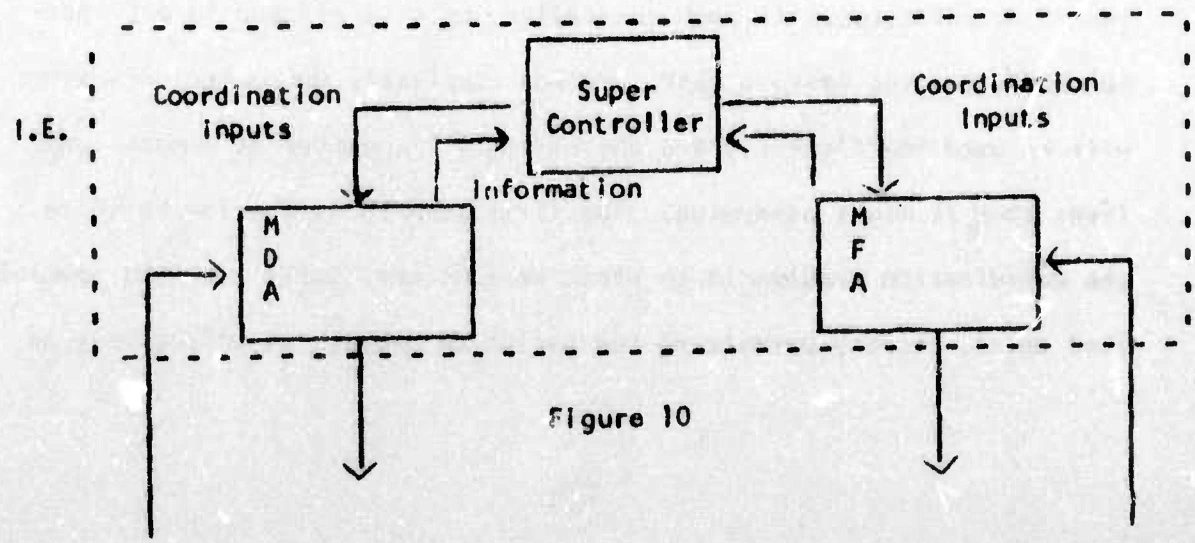


Figure 10

Depending upon the dimensions of the power, satisfaction, and defense units, the system cost of ignoring the coupling can be very high. Further examples of this type can be found in Mesarovic, et al. (1970) and Bailey and Holt (1971).

This illustration demonstrates once again how interdependent are goals, I.E. structures (including the image) and the O.E. Most all I.E.'s will have a structure similar to that of Figure 10, that is, the elements of the I.E. will be arranged hierarchically. Hierarchy here means "...a system that is composed of interrelated sub-systems, each of the latter being, in turn, hierarchic in structure until we reach some lowest level of elementary sub-system." (Simon (1969), p. 87) Mesarovic, et al. (1970, p. 22) suggest some reasons why we find multi-goal systems so often arranged in a hierarchical fashion: "...the overall goal of the organization which reflects the purpose of the organization as a whole is broken down into a sequence of sub-goals, so that the solution of the overall goal is replaced by the solution of the family of sub-goals."

However, as has been seen, specialization brings with it the problem of coordination. If each specialized unit is allowed to act independently and the various tasks are not completely uncoupled, resources will be used inefficiently and the nation will perform at a much lower level than it might otherwise. The first step in attempting to solve the coordination problem is to place more general units over the specialized units, thereby permitting the nation to operate as effectively as

possible. This is the procedure which was illustrated in the previous example. Figure 8 then represents a two-level, hierarchical structure. In this diagram the upward arrows refer to information and the downward arrows to coordination controls. The hierarchical, multilevel structure greatly reduces the amount of information which must be digested by any one group. As one moves up in level, the detail of information concerning each goal is reduced, thus allowing more goals to be considered at once. This increase in the number of goals presents significant problems to the decision makers attempting to implement them and to evaluate performance in achieving them. In order to discuss these difficulties, it is necessary to first be more explicit about some of the other elements in the problem structure.

The I.E. may be thought of as facing a decision as to what inputs (<u>u</u>'s) it ought to send into the O.E. to best move or retain the system in a desired state. The inputs are chosen by the I.E. on the basis of its image of the dynamics of the O.E. The decision problem is then defined by the goals, the interfaces, and the image. There are several ways the I.E. can modify its decision problem.

For example, it can change the image so that goals which previously looked unattainable now look attainable. Or, the I.E. can modify its goals in a way to make them attainable given the present image. It is in this way that goals can become changed or the structure of the I.E. can become modified. Third, it can construct new interfaces which allow the implementation of policies which previously were not

feasible. These first two techniques were to some extent treated in the previous paragraphs. To deal with the third (interface modification), the two interfaces must be examined in more detail.

This requires a look at how the government is able to put inputs into the O.E. and how it can monitor changes in the O.E.; that is the "hook-up" between the I.E. and the O.E. This "hook-up" has already been divided conceptually into two parts--the access interface and the observation interface. Both of these interfaces must generally be effective if the I.E. is to have a good chance of achieving its goals.

An important component of a nation's observation interface is some sort of social indicator system. Here "indicator system" is used in a very general sense to denote some set of O.E. elements whose values are measured at various points in time. GNP and unemployment rate might be two examples of economic indicators. Regime popularity and incidences of political violence might be several political indicators. The values of these interface measures are then evaluated by the I.E. in terms of its image of the O.E. and in part on the basis of this evaluation new policy outputs are generated.

The importance of an appropriate observation interface is again illustrated by the U.S. experience in Viet Nam. Following a crisis situation in Viet Nam (such as Tet), the U.S. response was to introduce some policy changes--generally in the form of increased military support to South Viet Nam. Ellsberg (1972) describes the characteristic Viet Minh and Viet Cong response to increased U.S. intervention:

"After suffering initial setbacks they would lie low for an extended period, gather data, analyze experience, develop, test, and adapt new strategies, then plan and prepare carefully before launching them (1972, 120)."

The U.S., however, monitered "enemy" strength through its field commanders who in turn equated frequency of enemy contact with enemy strength. If the enemy is strong, the reasoning went, then it will fight. If it is quiet, then it must be weak. Based on these reports, the tendency was always for the President to view his policy changes as a "success" which of course led to the periods of optimism and goal change discussed earlier. However, the U.S. observation interface was bad. Decreased contact did not mean a weakened enemy and, indeed, the periods of greatest crisis came at the times of highest U.S. optimism.

If policy outputs are to have any effect upon the O.E., the I.E. must have some way to get them into the O.E. This is done through the access interface. A task of the inner environment may often be the building of this interface prior to generating some other set of policy outputs. Thus a nation desiring to institute some land tax program based upon crop yield must first build an observation interface through which they can fairly accurately monitor crop production. It also must create some sort of access interface which will enable it to collect the taxes due it. Certain kinds of tax programs are often pursued in certain O.E.'s because, though they may have a slightly lower yield than other

feasible policies, of the ease of interfacing them with the O.E. An example in many U.S. states is the sales tax where the initial collection is made by already existing merchants and the amount collected is "naturally" controlled by sales volume.

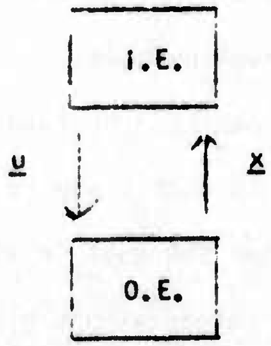
Indeed, it may often be the only way for a government to achieve its goals is through the construction of new interfaces or the modification of old ones. The current controversy over wage-price controls in the United States may be seen as a debate on what access points the government requires in the O.E. if it is to achieve certain social and economic objectives.

Thus far little attention has been paid to the international system--the O.E.--in which the national system--the I.E.--is attempting to achieve its goals. In light of last chapter's extended discussion of complexity, a first question might be, "Is it possible to construct an I.E. which is capable of adapting to any O.E. whatsoever?" Clearly if such universal adaptive structures can be shown to exist (in the mathematical sense of exist), then effort ought to be expended to translate a description of this structure into political terms.

More specifically, in political science terms, this question might be rephrased as "Is it possible to construct a government (I.E.) which is capable of adapting (maintaining state variables within specified limits) to any foreign or domestic environments (O.E.) it might be required to deal with?" Since such "universal governments" by definition can adapt to any O.E., the existence of such governments would greatly

reduce needs to acquire knowledge of specific O.E.s. However, the next Theorem (due to Gold (1965, 1971)) will show that such universal adaptors are impossible.

To make the problem simpler to conceptualize (but no less general), consider artificial systems whose access interface, observation interface and O.E. image are perfect. That is to say, that the I.E. can observe anything it chooses in the O.E. directly and without error, that it can put in "policies" exactly where, when and how it intends, and its image of the O.E. is (subject to certain constraints which will become clear) the O.E. itself. Thus the artificial system may be represented in its "reduced" structure as follows:



"Reduced" Artificial System Structure

Adaptation generally entails some sort of over time behavior and we can choose a time measure which is quantized (i.e. jumps from one unit to the next rather than being continuous) and has a finite starting point:

$$t = 1, 2, 3, 4, \ldots$$

At each time point, the I.E. sends control outputs ($\underline{u}$) into the O.E.

These $\underline{u}$ values can be thought of as being chosen from some finite alphabet U. Further, at each time point the O.E. receives inputs ($\underline{x}$) from the O.E. The $\underline{x}$ vector may be thought of as consisting of two components. The first, $\underline{p}$, are performance measures (e.g., level of satisfaction, etc.) and the second, $\underline{i}$, are (nonperformance) information about the O.E. The values of $\underline{p}$ are expressed in a finite alphabet P and the values of $\underline{i}$ in a finite alphabet I. (These three alphabets need not be different, only distinguishable). Thus:

$$\underline{u}_t \in U$$
$$\underline{p}_t \in P$$
$$\underline{i}_t \in I$$

Again, without significant loss of generality, assume each of these alphabets to be coded as real numbers.

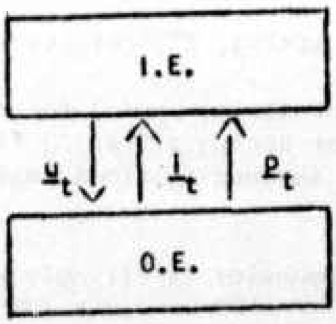
An inner environment can then be said to be adaptive if it is able to choose sequences of $\underline{u}_t$ in such a way as to bring and maintain $\underline{p}_t$ within specified limits. Note that the goal is simply to bring $\underline{p}$ into some desired interval. The $\underline{i}_t$ values simply give the I.E. information about the process but do not themselves enter directly into the I.E.'s objective(s).

Still, however, the problem as posed does not have enough structure to be solved. More must be said about what kinds of O.E.s and I.E.s are being examined. A way of accomplishing this is to limit the class of possible I.E.s to those which have a finite number of states (that is, the I.E. at any point in time can only be in one of a finite number of states where state is used in precisely the same sense as earlier

and the class of O.E. to the class of finite automata (see Holt and Richardson (19__). The problem then becomes: "Is there a universal I.E. which will adapt to any (finite automaton) O.E.? Paraphrasing Gold (1971), it can be proven:

> For any I.E. (finite state), there exists a finite state O.E. such that the I.E. will always behave in a strongly worst way.

In the argument which follows, an <u>alphabet</u> is defined as a non-empty set of real numbers and where A is the alphabet, A* signifies the set of finite strings of elements in A. The three alphabets we will be referring to are U (policy outputs from the I.E.), P (performance inputs from the O.E.) and I (information inputs from the O.E.). Thus:



The O.E. can be thought of as a function O_I from U* to I together with a function O_P from U* to P. In other words, the outputs of the I.E. (U*) determine I and P for the O.E. That is, we can say the I.E. and O.E. are linked. The I.E. then is a function E from (I X P)* to U. The outputs (U) of the I.E. are determined by the pairs of i and p values generated by the O.E. (in response to previous u's). More formally:

$$O_i: \; U^* \longrightarrow I$$
$$O_p: \; U^* \longrightarrow P$$
$$E: \; (I \times P)^* \longrightarrow U$$

These functions will result in the following sequences:

$$i_t = O_i\,(u_1, u_2, u_3, \ldots u_{t-1})$$
$$p_t = O_p\,(u_1, u_2, u_3, \ldots u_{t-1})$$
$$u_t = E\,(i_1, p_1; i_2, p_2; i_3, p_3; \ldots i_{t-1}, p_{t-1})$$

The sequence of I.E. outputs $u_1, u_2 \ldots$ is, as before, called the behavior of the I.E. With this vocabulary, strongly worst behavior can be defined. Suppose the set of P values is binary:

$$P = \{0, 1\}$$

p = 0 might be interpreted as undesirable and p = 1 as desirable. A <u>strongly worst</u> behavior string, B^W, results if:

1) For the behavior string $p_t = 0$ for all t but,
2) for any behavior string differing from B^W at any time, $p_t = 1$ for all succeeding times regardless of future values of u_t.

In other words, a behavior is strongly worst if it results in the lowest possible value of p_t for all t and any other behavior would result in the highest possible value of p_t for all t. Certainly an I.E. which behaves in a strongly worst manner is not behaving adaptively no matter how wide a range is put on "acceptable limits." Thus if it can be proven that given any finite state I.E., a finite state O.E. can always be constructed toward which the I.E. will behave in a strongly worst manner, it will have been proven that there exists no universal I.E.

Suppose that the O.E. sends out a constant value of I for all t:

$$i_t = i \text{ for all } t$$

Thus the values of i are "independent" of the behavior of the I.E. When $i_t = i$ and $p_t = 0$ for all t, let the I.E. pass through States s_1, s_2, s_3... producing outputs o_1, o_2, o_3...Since, by assumption, the I.E. has a finite number of states, it will finally have to repeat a state. Let s_{n+1} be the first repeated state of the sequence $s_{n+1} = s_m$, where $m \leq n$. Then by assumption u_t must have the same period thereby yielding $o_{n+1} = o_m$. Let the O.E. have n + I states S_0, S_1, ... S_n such that the O.E. is in S_0, it will send back $p_t = 1$; all other O.E. states will send back $p_t = 0$. Let S_1 be the initial (at t = 1) state of the O.E. Finally then we can specify the state transformation rules of the O.E. as follows: (where $\longrightarrow$ may be read as "moves to")

$$\text{(i)} \quad S_0 \longrightarrow S_0 \text{ for all } u_t$$

$$\text{(ii)} \quad S_j \longrightarrow S_{j+1} \text{ if } u_t = o_t$$

$$\text{(iii)} \quad S_j \longrightarrow S_0 \text{ if } u_t \neq o_t$$

$$\text{where } j = 1, 2, \ldots n \text{ and } S_{n+1} = S_m$$

For example, if the O.E. is in State S_j and receives an input $u_t \neq o_t$, it will move to S_0 and remain there for all future time regardless of future values of u_t. This yields a constructive proof that, if the O.E. is allowed to have as few as one more state than the I.E., an O.E. toward which the I.E. will behave in a strongly worst manner will always exist.

An example might make this more clear. Suppose $n = 3$ (that is, the number of I.E. States equals 3). At $t = 1$:

<u>t</u>	<u>I.E.</u>	<u>O.E.</u>	<u>i</u>	<u>u</u>	<u>p</u>
1	s_1	S_1	i	o_1	0

Since the O.E. is not in S_0, $p_1 = 0$. Further, since $u_1 = 0_1$ did not result in a desirable value of p_1, the I.E. will move to another state:

<u>t</u>	<u>I.E.</u>	<u>O.E.</u>	<u>i</u>	<u>u</u>	<u>p</u>
1	s_1	S_1	i	o_1	0
2	s_2	S_2	i	o_2	0

Again, $u_2 = o_2$ produces an undesirable value of p_2 and, because $u_2 = o_2$, the O.E. moved into State S_2 as specified by transition rule (ii). Time 3yyields the same results:

<u>t</u>	<u>I.E.</u>	<u>O.E.</u>	<u>i</u>	<u>u</u>	<u>p</u>
1	s_1	S_1	i	o_1	0
2	s_2	S_2	i	o_2	0
3	s_3	S_3	i	o_3	0

The I.E. has now exhausted its states. Suppose it moves back again to S_1 (i.e., $m = 1$) thereby again going through the cycle. Here, then, is an example of how an O.E. with one more state than a given I.E. can always be constructed so that the I.E. will behave in a strongly worst manner.

This theorem proves that given an I.E., there will always exist an O.E. which is complex relative to that I.E. (complex in the sense of having more states) in which the I.E. will be unable to behave adaptively (no matter how weakly "adaptively" is defined). Additional theorems

have been proven (Gold, 1966, 1971) to demonstrate that even for teams of adaptors utilizing various strategies, there exist environments for which they will behave in a strongly worse manner.

The import of these results to political theory is not altogether clear. That there exist (in the mathematical sense) complex outer environments in which any given inner environment will behave in a strongly worst manner, is not, of course, to demonstrate that the particular outer environments in which national systems are located are of this type. It would seem plausible, however, at least that the outer environment of any national system has more system-states than does the national system itself. This is especially compelling if the national system is seen to be a part of its own O.E. At the very least, these results suggest that in designing governments, it is probably futile to attempt to construct a government which is capable of adapting to all O.E.'s. Instead careful study should be given to classifying the range of O.E.s likely to be encountered by the government.

Section V: Complexity and the International System

One way of classifying O.E.s might be in terms of their complexity relative to a given I.E. As was argued elsewhere (Thorson, 1972) the notion of complexity involves enormous analytic, conceptual and empirical problems. However, regardless of these difficulties, complexity has the advantage of being in part contingent upon national system structure and of fitting in nicely with some aspects of organization theory. The utility of these characteristics should become more apparent in the ensuing discussion.

While it seemed to make intuitive sense to argue that some systems (e.g., O.E.s) are inherently more complex than others, such a "non-contingent" view of complexity often leads to more problems than it resolves. What seems to be true is that no satisfactory definition of the complexity of an environment can be given independent of the class of systems "operating" in that environment. The reason for this is that the system can be so designed as to remove some of the "intuitive complexity" from the environment. For example, many living species may well be facing a less complex environment now than they did thousands of years ago. Through evolution many of the common relational structures have been "pre-programmed" into the human brain. The brain has developed in such a way as to operate extremely effectively in an environment of three dimensions, fast response times (the time it takes for the environment to respond to external stimuli), and few relevant variables. This pre-programming of complexity through evolution

or design may well be a key to any system's operating adaptively in a seemingly complex environment.

What of the international political system (a foreign policy maker's O.E.)? It is doubtful that the international political system is of the three dimensional, fast response time, and few relevant variable type. Indeed, the "high order, multiple loop, non-linear feedback structure" discussed by Forrester (1969) would seem to be far more descriptive of the international system:

> It has become clear that complex systems are counter-intuitive. That is, they give indications that suggest corrective action which will often be ineffective or even adverse in its results. Very often one finds that the policies that have been adopted for correcting a difficulty are actually intensifying it rather than producing a solution.
>
> Choosing an ineffective or detrimental policy for coping with a complex system is not a matter of random choice. The intuitive processes will select the wrong solution much more often than not. A complex system--a class to which a corporation, a city, an economy, or government belong--behaves in many ways quite the opposite of the simple systems from which we have gained our experience.
>
> Most of our intuitive responses have been developed in the context of what are technically called first-order negative-feedback loops. Such a simple loop is goal-seeking and has only one important state variable. For example, warming one's hands beside a stove can be approximated as a first-order, negative-feedback loop in which the purpose of the process is to obtain warmth without burning one's hands. The principal state variable of the loop is the distance from the stove. If one is too close he burns his hand, if too far away he receives little heat. The intuitive lesson is that cause and effect are closely related in time and space. Temperature depends on the distance from the stove. Too much or too little heat is clearly related to the

position of the hands. The relation of cause and effect is immediate and clear. Similarly, the simple feedback loops that govern walking, driving a car, or picking things up all train us to find cause and effect occurring at approximately the same moment and location.

But in complex systems cause and effect are often not closely related in either time or space. The structure of a complex system is not a simple feedback loop where one system state dominates the behavior. The complex system is of high order, meaning that there are many system states (or levels). It usually combines positive-feedback loops describing growth processes as well as negative, goal-seeking loops. In the complex system the cause of a difficulty may lie far back in time from the symptoms, or in a completely different and remote part of the system. In fact, causes are usually found, not in prior events, but in the structure and policies of the system.

To make matters still worse, the complex system is even more deceptive than merely hiding causes. In the complex system, when we look for a cause near in time and space to a symptom, we usually find what appears to be a plausible cause. But it is usually not the cause. The complex system presents apparent causes that are in fact coincident symptoms. The high degree of time correlation between variables in complex systems can lead us to make cause-and-effect associations between variables that are simply moving together as part of the total dynamic behavior of the system. Conditioned by our training in simple systems, we apply the same intuition to complex systems and are led into error. As a result, we treat symptoms, not causes. The outcome lies between ineffective and detrimental.

Actions directed at individual nations often have indirect and unforseen consequences. Sometimes these consequences take years and even decades to make themselves known. Solutions to specific problems often result in making things worse rather than better. In short, nations' foreign policy responses often have not been well selected. This poor selection may stem partly from man's proclivity to look in the international environment for kinds of relational structures of encounters in his day to day experience.

The complexity of the international environment is in part dependent upon the structure and goals of the national system which is attempting to deal with it. Thus different national systems may view a given international environment as more or less complex. It is, however, possible to identify some characteristics to look for in environments:

(1) The number of relevant variables. In general, the greater the number of relevant variables, the more complex the environment.

(2) The response time of the environment. In general, the longer it takes for an environment to respond to foreign policy inputs, the more complex it is.

(3) Amount of randomness in the environment. Here the concern is with how much variance is associated with the response of the international environment to a given foreign policy input from a given national system. The greater the variance, the greater the randomness. In general, the greater the randomness, the more complex the international environment.

With relatively few additional assumptions, these notions can be used to derive a number of qualitative propositions relating the complexity of the international system (O.E.) to the foreign policy responses of an adaptive national system (I.E.). While the deviation of these propositions is outside the scope of this chapter, one such proposition will be derived as an example of the procedure which might be employed.

It has been assumed that a national system generates foreign policy outputs in a way designed to achieve certain goals. These goals may be thought of as desired system states. It was noted that outputs

of adaptive systems are chosen as a result of a historical record together with the present system state. It was also stated that adaptive systems may at times make the "wrong" choice. By a wrong choice it is meant that the system could have chosen a different output which would have resulted in the system's moving to a more desired state. Through the feedback process the system can generally assess the effect of its output and correct certain kinds of errors.

In this discussion it will be assumed that some sort of learning mechanism is present in the national system. This learning mechanism will be a member of the class of familiar trial and error types. Each time the system has to generate a foreing policy output, a number (this number may be one, of alternatives are considered. Each of these alternatives has associated with it some probability of being chosen as the foreign policy. After an output is chosen, its effect is evaluated by some decision component according to some rule. After this evaluation, the alternatives are assigned new probabilities of being chosen. This sort of decision procedure will generally yield a negatively accelerating learning curve as in Figure 11.

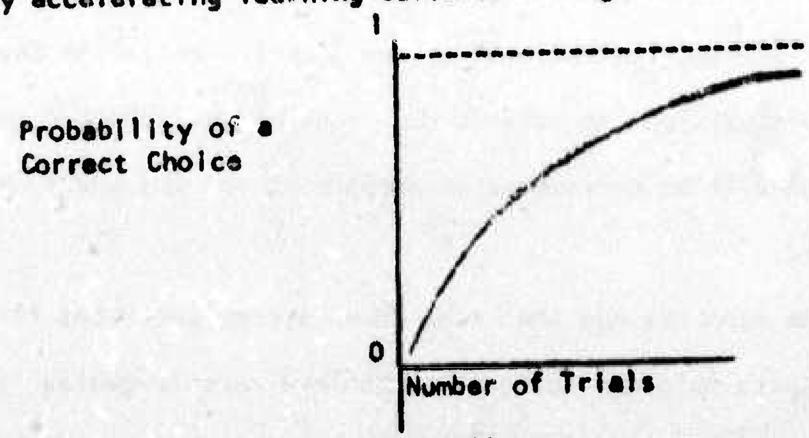


Figure 11

By a correct foreign policy it is meant a foreign policy output which will result in meeting some well-defined goal, i.e., an adaptive behavior. In some cases there may be more than one correct choice. The curve of Figure 11 will still hold. What Figure 11 is saying is that, in general, the probability of a correct choice increases with the number of trials.

More specifically, it will be assumed that the particular learning mechanism will be one similar to that described by Norman (1964) and that the foreign policy responses generated by the I.E. are made on the basis of information gained from previous responses in situations deemed similar. It is further assumed that there exists an optimal policy (in the sense defined earlier), and it is the task of the I.E. to identify and implement this policy. (This formulation ignores Simon's (1957) claim that large scale organizations will often exhibit "satisficing" rather than optimizing behavior)!

The probability of the I.E. choosing a sub-optimal policy will be some number "q" where $0 \leq q \leq 1$. In describing foreign policy behavior, the task then becomes to relate the value of "q" on one trial to that of "q" on another. A trial is simply a perception on the part of the I.E. of a decision problem together with the I.E. policy response to that decision problem. In psychological terms, the perception of a decision problem corresponds to the stimulus and the chosen policy as the response.

In a theory of I.E. policy selection, all those trials in which the relevant component of the I.E. perceives the decision problem in a

similar way can be treated as an equivalence class of events (trials). It is responses to trials which belong to the same equivalence class that the theory will attempt to describe. Again, in the vocabulary of learning theory all trials which have "similar" stimuli will be considered to be in the same equivalence class independent of the I.E.'s selected policy response.

With the help of the preceeding vocabulary, the specific learning mechanism being posited can be described more rigorously. On each trial "n", the I.E. will respond with a sub-optimal policy with a probability "q_n" and with an optimal policy with a probability "p_n" where, of course:

$$(6) \quad p_n = 1 - q_n$$

On any given trial, the I.E. may or may not learn from its response how to better respond on the next trial. This will be represented by a random variable "y_n" which will equal one if learning took place on trial "n" and zero if no learning took place. Further, the probability that learning takes place on any trial will be represented by "c." Thus:

$$(7) \quad y_n = \begin{cases} 1, \text{ with probability } c \\ 0, \text{ with probability } 1-c \\ \text{where } o \leq c \leq 1 \end{cases}$$

The main axiom describing this learning mechanism describes the relation between the probability of selecting a sub-optimal policy on one trial and that of selecting a sub-optimal policy on the succeeding trial. It can be stated in a single difference equation:

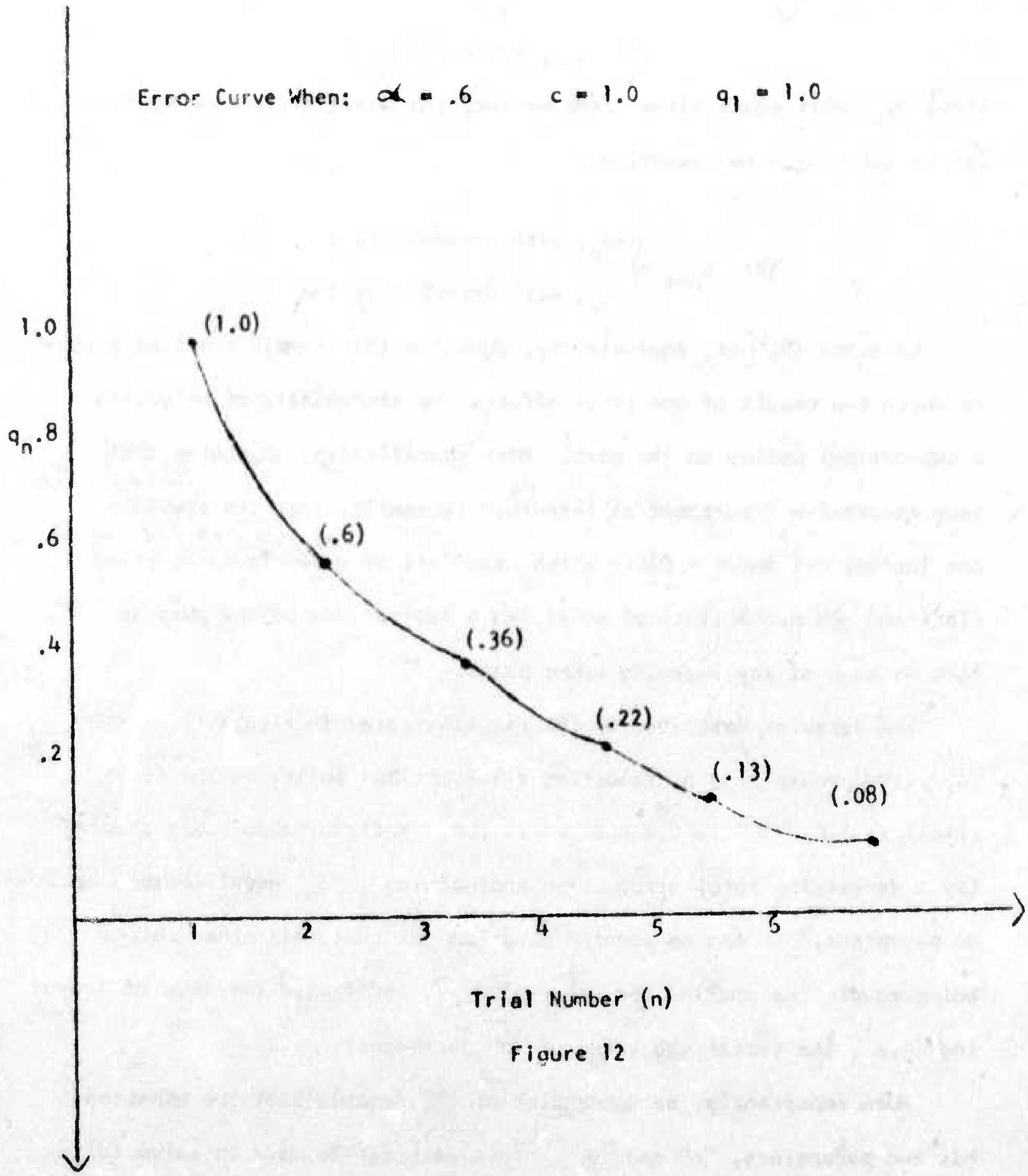

Error Curve When: α = .6 c = 1.0 q1 = 1.0
1.0
qn .8
.6
.4
.2
(1.0)
(.6)
(.36)
(.22)
(.13)
(.08)
1
2
3
4
5
6
Trial Number (n)

Figure 12

$$(8) \quad q_{n+1} = \alpha^{y_n}(q_n)$$

Since "y_n" will equal either zero or one, the above difference equation can be split into two equations:

$$(9) \quad q_{n+1} = \begin{cases} \alpha q_n, & \text{with probability } c \\ q_n, & \text{with probability } 1-c \end{cases}$$

Equation (8) [or, equivalently, equation (9)] simply provides a rule by which the result of one trial affects the probability of selecting a sub-optimal policy on the next. More specifically, it states that each successive "increment of learning" is smaller than the previous one (unless $c = 1$ and $\alpha = 0$) in which case "all or none" learning takes place and the probability of selecting a sub-optimal policy goes to zero as soon as any learning takes place.

The behavior described by (8) is illustrated in Figure 12. Here "q_1" (the probability of selecting a sub-optimal policy on the first trial) is 1.0, "α" is 0.6 and "c" is 1.0. Notice the downward sloping (at a decreasing rate) error curve approaching "q_n" equal to zero as an asymptote. It can be seen in equation (8) that, all other things being equal, the smaller the value of "α", the faster the rate of learning (i.e., the faster the value of "q" decreases).

More importantly, an inspection of (8) reveals that the equation has two parameters, "c" and "α". This fact can be used to solve (8) for various statistics in terms of "α" and "c". For our purposes two of the most important statistics are the expected number of sub-optimal

responses in an infinite number of trails E(T) and the variance about the expected total number of sub-optimal responses var (T). Equations in terms of "c", "" and "q " for these two statistics can be derived from (8) above (for the derivations of these as well as other statistics see Norman (1964) to yield:

$$(10) \quad E(T) = \frac{q_1}{c(1- \ )}$$

$$(11) \quad var\ (T) = E(T) \left[1 + \frac{2}{q_1} \left(\frac{q_1{}^2 + (\ c + 1 - c)}{c(1- \ 2)} \right) - E(T) \right]$$

If there is no additional information, "q " is generally thought to equal $(1 - \frac{1}{r})$ where "r" is the number of alternative policies and (since the I.E. has no additional information) the I.E. must simply select one "at random." From (10) it is clear that (all other things being equal) as "q " gets larger, E(T) gets larger. That is, under the posited learning mechanism the larger the initial probability of selecting a sub-optimal policy, the greater will be the expected total number of sub-optimal policies which will be selected.

Based upon the previous discussion, it can be said that with respect to a fixed I.E., and a given decision problem, O.E. becomes more complex as it becomes more "difficult" for the I.E. to respond with an optimal policy. Moreover, the learning mechanism described above permits an unambiguous (though not necessarily unobjectionable) index of the difficulty of a decision problem -- the greater the value of E(T) for a given decision problem the greater the difficulty of that decision problem. As has been seen, E(T) is dependent upon "q ", "c" and "" and will increase with decreases in "q " or "c" or increases in "".

In most instances the values "q_1" and "α" (the learning rate parameter) would seem to be dependent upon the structuring of the I.E. This may not be the case with "c." In terms of the theorem proved earlier concerning the impossibility of a universal adaptor, "c" reflects the probability that performance information in $\underline{p}_t$ will be used in such a way as to decrement the value of q_t on the next trial (it would be interesting to change the learning mechanism to allow information to be utilized in such a way as to actually increment the value of q_t [as in some kinds of hypothesis learning]). As the value of "c" decreases, both E(T) and var(T) increase dramatically as can be seen in Table 4.

Table 4

Values of E(T) and var (T) for selected values of "c"
[q_1 = .667, α = .5]

	E(T)	var(T)
c = 1.0	1.33	0.74
c = 0.5	2.0	3.34
c = 0.1	13.34	45.49

The parameter "c" might be interpreted as being the probability that the O.E. will send a "usable" (i.e., one that enables learning to take place) performance response to the I.E. The greater the value of "c" the fewer the expected total number of sub-optimal policy outputs and the smaller will be the variance about this expectation. In general, it would be thought that sub-optimal policies would (assuming an effective access and observation interface) be followed by an O.E. response indicating "low" performance and the value of "c" would be very high.

However, if there is considerable randomness in the O.E. this need not be the case as the performance response of the O.E. to equivalent policy inputs would not be deterministic, but rather would be governed by some probability function. The probability that effective learning would take place on any given trail (c) would generally decrease as the randomness in the O.E. increases.

It seems plausible to argue that as the randomness of the O.E. increases its complexity will either remain the same (if the increased randomness does not affect the particular decision problem being studied) or increase (if the increased randomness does affect the decision problem). In the rest of this paper "increased randomness" will refer only to the later case where the particular decision problem of interest is affected. With this restriction on the use of "increased randomness," it seems that increases in the randomness will increase the complexity of the O.E. by decreasing the value of "c."

If this be so, a proposition relating changes in the complexity of the O.E. to the variance [var(T)] of the O.E.'s foreign policy behavior immediately follows (it will be assumed that the interfaces are constant and effective enough to handle the outputs generated and to adequtely observe their effects.)

<u>Proposition</u>: The more randomness in the international environment, (O.E.) the greater will be the overtime variance [var(T)] in a national system's foreign policy outputs.

This proposition asserts that when a given policy output does not have the same effect upon the environment, the national system moves from policy to policy in an attempt to find a correct one. Supposing there is a correct response, the randomness in the environment may, at times, have the effect of making a "correct" choice appear incorrect. Thus it will take more trials to learn the correct response and there will be considerable movement about the set of possible responses. The result of this will be to make the national system operating in such an environment appear to have a vacillating or inconsistent foreign policy. An example of this might be U.S. foreign aid policy since World War II. Here the U.S. appears unable to decide whether foreign aid should take the form of large amounts of dollars or technical assistance. One could argue that this vacillation is the result of not getting similar environmental responses from policy outputs which were thought to be the same. Thus the U.S. cannot decide between big money and technical assistance.

The derivation of this proposition under the particular learning mechanism being posited should be clear from the earlier discussion. Increasing the randomness in the O.E. results in decreasing "c" and as "c" decreases, var(T) increases (see Table 4 for a numerical example).

While there are a number of other propositions which could be made relating the complexity of the environment to national foreign policy behavior, it is important to mention some possible effects of the interface on foreign policy outputs.

So far, it has been assumed that the interfaces were constant and effective. In many cases this assumption is not valid. There are times when the national system simply cannot access the environment in the way that it wants. As a result, it cannot achieve certain of its desired states. Even more often there are problems with the observation interface. Either the national system does not know that variables to look at to assess its policy or the variables are not directly observable and measures for them are unreliable. Some of the controversy over arms limitations may be seen as stemming from difficulty in the observation interface. Here the stakes are very high, and the national system is not certain it can measure accurately the effect of an arms limitation policy. In such a circumstance it is highly unlikely that a limitation policy will be put into effect. The reason for its not being adopted may be due not to uncertainty in the environment but rather to being unable to adequately observe the state of the environment. Generally when it is thought an output choice could possibly result in moving the national system to a highly undesirable state if it is not corrected quickly and if its effect is not observable, then the output will probably not be generated even though it is highly probable that the outcome will be very favorable to the national system. This proposition in effect says that the adaptive national system will not attempt to optimize on a particular objective if it realizes that it could be badly hurt if the environment does not respond to its policy the way it forecasts it will and the national system cannot observe quickly enough what the environmental response is.

In view of these few propositions, certain foreign policy strategies become apparent. For example, if the environment is fairly random, a nation wanting to meet some goal might first try to structure the environment to make it more predictable. This notion is implicit in British foreign policy in the 19th century. Further, Alger (1961) has speculated that one of the effects of the United Nations is to make the world more predictable. This in turn means national policies can be more consistent.

Conversely, a national system which was a part of another national system's international environment might want to make its responses somewhat random to force the second nation into adopting an inconsistent policy toward it. Thus, for certain purposes a nation might want to increase the randomness in the international system.

Certainly none of the propositions which have been made are "new" to the study of foreign policy. They can be found, in various forms, throughout the literature. However, that they follow from the framework developed in this paper is of some interest. For this framework gives a language and a structure with which we can relate the national system to its international environment. Relatively few propositions have been presented of the many that could have been. The purpose, however, of this paper has not been to introduce propositions, but to sketch a unified perspective from which to begin to theorize about a "complex" social phenomenon--national foreign policy behavior.

Summary

If foreign policy behaviors are to be viewed as being generated by adaptive national systems, then a language appropriate to this focus must be introduced. The concepts surrounding Simon's notion of an "artificial" system provide one such vocabulary. Artificial systems may be thought of as a subset of general systems and are characterized by such concepts as "goals", "inner environments", "outer environments", and "interfaces." An adaptive national system was then defined as a government (I.E.) attempting to achieve goals (maintain state variables within specified limits) in an O.E. consisting of (at one level of disaggregation) the domestic environment and the interactional system. Several additional components of adaptive systems were mentioned and some of their implications for national systems were discussed. The definition of an adaptive system was employed to prove the impossibility of a universal adaptor and this result was used to suggest that O.E.'s be classified as to their complexity with respect to a given I.E. (national system). An illustrative proposition was derived utilizing this approach.

References

Ackoff, R. Scientific Method: Optimizing Applied Research Decisions. Wiley: New York, 1962.

C. Alger (1961), "Non Resolution Consequences of the United Nations and Their Effect on International Conflict," in Journal of Conflict Resolution, Vol. V, No. 2 (June, 1961), pp. 128-145.

Ando, A., F.M. Fisher, H.A. Simon (eds.), Essays on the Structure of Social Science Models (Cambridge, Mass,: M.I.T. Press, 1963).

Arbib, M.A., "Automata Theory and Control Theory--A Rapprochement," Automatica, III, pp. 161-189.

Arbib, M.A., Theories of Abstract Automata (Englewood Cliffs, N.J.: Prentice Hall, 1969.

Ashby, W.R. (1952), Design for a Brain, Butler and Tanner Ltd., (Fromme and London).

Ashby, W., "What is an Intelligent Machine?," in Ludwig Von Von Bertalanffy and Anatol Rapoport (eds.), General Systems Yearbook, Vol. VIII, 1963.

Bailey, F. and R. Holt, "Towards a Science of Complex Systems," mimeo, 1971.

Barnett, Lincoln, The Universe and Dr. Einstein (New York: Harper and Brothers, 1948).

Blum, M., "A Machine-Independent Theory of the Complexity of Recursive Functions," J.A.C.M., XIV, pp. 332-336.

Bobrow, "International Indicators," paper prepared for delivery at the 1969 Annual Meeting of the American Political Science Association, Commodore Hotel, New York City, 2-6 September 1969.

Botvinnik, M., Computers, Chess and Long-Range Planning (Springer-Verlag, 1970).

Brandl, John, "Constrained Maximization and Decision Rules in Government: An Analysis of an Investment Allocation Formula," mimeo, undated.

Brunner R., and Brewer, G. Organized Complexity. New York: Free Press, 1971.

Brunner, Ronald, "Data Analysis, Process Analysis, and System Change," paper prepared for delivery at the 1970 Annual Meeting of the American Political Science Association.

Cain, G. and H. Watta, "Problems in Making Policy Inference from the Coleman Report," American Sociological Review, (April, 1970). pp. 228-252.

Carr, E.H. (1944), Conditions of Peace, The MacMillan Company, (New York).

Coghill, G., Anatomy and the Problem of Behavior, C.U.P., 1929.

Coombs, C., R. Dewes, and A. Tversky, Mathematical Psychology (Englewood Cliffs, N.J.: Prentice Hall, Inc., 1970).

Ellsberg, D. Papers on the War. Simon and Schuster: New York, 1972.

Fogel, L., A. Owens, and M. Walsh, Artificial Intelligence through Simulated Evolution (New York: John Wiley & Sons, Inc., 1967).

Formby, J., An Introduction to the Mathematical Formulation of Self-Organizing Systems (E. & F.N. Spon, 1965).

Forrester, J., Urban Dynamics (Cambridge, Mass.: M.I.T. Press, 1969).

Forrester, J. Industrial Dynamics. M.I.T., Cambridge, 1961.

Geoffrion, A. Proper Effeciency and the Theory of Vector Maximization. Journal of Mathematical Analysis and Applications, 1968, 22(3), 618-630.

Gold, E. Universal Goal Seekers. Information and Control, 1971, 18, 395-403.

Gold, E. Models of Goal-Seeking and Learning. (Doctoral dissertation, UCLA) Ann Arbor, Mich.: University Microfilms, Inc., 1965.

Gregory, R., "On How so Little Information Controls so Much Behavior," in Toward a Theoretical Biology 2 (Edinburgh University Press, 1969).

Gunn, J. The Problem of Time. Allen and Unwin, 1929.

Hanrieder, W. (1967), "Compatability and Consensus: A Proposal for the Conceptual Linkage of External and Internal Dimensions of Foreign Policy," American Political Science Review, LXI (December, 1967), pp. 971-982.

Holt, R. and J.M. Richardson, Jr., "Applications of Automata Theory to the Explanation of Political Development," paper prepared for delivery at the 1969 Annual Meeting of the American Political Science Association.

Hull, C. Principles of Behavior. New York: Appleton, 1943.

Kanter and Thorson, The Logic of U.S. Weapons Procurement. In Rosen, ed. Testing the Theory of the Military Industrial Complex (in press).

Kemeny, J., A Philosopher Looks at Science. (Princeton, N.J.: D. Van Nostrand, 1959).

Kulikowski, R., "Control and Organizational Structure in Large Scale Systems," Space Science Center, University of Minnesota, 1970.

Levins, R., "Complex Systems," in Toward a Theoretical Biology 3 (Edinburgh University Press, 1970).

McGowan, P. (1970), "A Formal Theory of Foreign Policy as Adaptive Behavior," Paper delivered to the 66th Annual Meeting of the American Political Science Association.

Mesarovic, M., D. Macko, and Y. Takahara, Theory of Hierarchical Multilevel Systems (New York: Academic Press, 1970).

Minsky, M., Computation Finite and Infinite Machines (Englewood Cliffs, N.J.: Prentice Hall, 1967).

Morgenthau, M. (1961), Politics Among Nations, 3rd Edition, Alfred A. Knopf, (New York).

Murphy, R.E., Jr. (1965), Adaptive Processes in Economic Systems, Academic Press, (New York).

Norman, M."Incremental Learning on Random Trials."J. Math Psychology 1, 336-350, 1964.

Ornstein, R. On the Experience of Time. Middlesex: Penguin, 1969.

Richardson, J. and Pelsoci, T."Measuring Satisfaction in Urban Systems." A preliminary report of the Urban Organizational Design and Control Project, Case Western Reserve University, mimeo, 1971.

Richardson, J. (1969), Partners in Development, Michigan State University Press, (East Lansing).

Rosenau, J. (1970), The Adaptation of National Societies: A Theory of Political System Behavior and Transformation, McCaleb-Seiler, (New York).

Rosenau, J. (1967), "Compatability, Consensus, and an Emerging Political Science of Adaptation," American Political Science Review, LXI, (December, 1967), pp. 983-988.

Samuelson, P. "Interactions Between the Multiplier Analysis and the Principle of Acceleration," Review of Economic Statistics, XXI, May, 75-78, 1939.

Shannon, C., "Programming a Computer for Playing Chess," Philosophical Magazine Vol. 41 (March, 1950).

Shaw, R., "Cognition, Simulation, and the Problem of Complexity," mimeo, 1970.

Shaw, R. and J. Jenkins, "Gedanken Experiments for Organisms too Complex to be Modelled," mimeo, 1970.

Simon, H., The Sciences of the Artificial (Cambridge, Mass,: M.I.T. Press, 1969).

Simon, H., Models of Man (New York: Wiley, 1957).

Tarski, A. Introduction to Logic, 3rd ed. Galaxy, 1966.

Thom, R., "Topological Models in Biology," in C.H. Waddington (ed.), Towards a Theoretical Biology 3 (Chicago: Adline Publishing Company, 1970).

Thom, R., "Une theorie dynamique de la morphogenese," in C.H. Waddington (ed.), Towards a Theoretical Biology 1 (Chicago: Aldine Publishing Company, 1968).

Thorson, S. "The Role of Mathematics in Political Theory Construction" (Doctoral Dissertation, University of Minnesota, 1972).

Thorson, S. "Modelling Social Processes as Dynamic Systems." Paper presented at the 1971 Annual Meeting of the American Political Science Association.

Toda, M. and E. Shuford, "The Logic of Systems: An Introduction to a Formal Theory of Structure," in Ludwig Von Bertalanffy and Anatol Rapoport (eds.), General Systems Yearbook, Vol. X (1965).

Von Neuman, J., "Rigorous Theories of Control and Information," in Theory of Self-Reproducing Automata (University of Illinois Press, 1966).

Waddington, C.H., Strategy of the Genes (London: Allen and Unwinn 1957).

Comments on Some Problems in Constructing Descriptive, Policy, and Design Theories of Foreign Policy Behavior

Stuart J. Thorson
Department of Political Science
Ohio State University

June 1973
Project Research Report No. 11

A Discussion Paper prepared for the Inter-University Comparative Foreign Policy Project Conference on the Future of Comparative Foreign Policy Analysis, Ojai, California, June 1973.

Support for this work was provided in part by the Advanced Research Projects Agency, ARPA Order No. 2345-3D20, Contract No. DAHC 15 73 C 0197, RF 3527-A1.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Project for Theoretical Politics The Ohio State University 053 Administration Building	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

"National Political Adaptation in a World Environment: Toward a Systems Theory of Dynamic Political Processes"

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Research Report # 10

5. AUTHOR(S) (First name, middle initial, last name)

Stuart J. Thorson

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
July 30, 1973	76	61

8a. CONTRACT OR GRANT NO. DAHC15 73 C 0197 b. PROJECT NO. A.O. 2345-3D20 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) # 10 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited and production in whole or in part is permitted for any purpose of the United States Government.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Advanced Research Projects Agency Washington D.C.

13. ABSTRACT

Foreign policy behavior is viewed as being generated by adaptive national systems, and a language appropriate to this focus is introduced. The concepts surrounding Simon's notion of an "artificial" system provide one such vocabulary. Artificial systems may be thought of as a subset of general systems and are characterized by such concepts as "goals", "inner environments", "outer environments", and interfaces." An adaptive national system is then defined as a government (I.E.) attempting to achieve goals (maintain state variables within specified limits) in an O.E. consisting of (at one level of disaggregation) the domestic environment and the international system. Several additional components of adaptive systems are mentioned and some of their implications for national systems are discussed. The definition of an adaptive system is employed to prove the impossibility of a universal adaptor and this result is used to suggest that O.E.'s be classified as to their complexity with respect to a given I.E. (national system). An illustrative proposition is derived utilizing this approach.

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Adaptive system						
Foreign Policy						
Artificial System						

UNCLASSIFIED
Security Classification

Introduction

Theories of foreign policy behavior--like theories of most anything else are developed with a variety of purposes. In this paper I want to discuss three such purposes. These are 1) description, 2) policy and 3) design. A discussion of these three is important since, as I will argue, the three are interrelated in various ways and it may well be helpful to construct theories with an awareness of some of these interrelations.

To make this argument, I must first clarify what I mean by a theory. Within political science (at least) the concept of a theory is one which takes on many meanings. To argue that one is more correct than others would be arrogant (and probably pointless). However, to assume that "everyone knows what a theory is" and thus not to define it is dangerous. Therefore, at the risk of appearing arrogant, let me make as precise as I can the way I will be using the term "theory."

Since this is a paper on the study of foreign policy and not on the definition of theory, I will attempt to accomplish this pre-task as briefly as possible. Probably the best way to achieve this is to identify some attributes of "theories" and then specify the exact set of attributes possessed by the things I'll be calling theories.

To begin, most all uses of theory agree that theories "exist" in languages. That is, they are sets of sentences. Thus one attribute of a theory is the kind of language (e.g., semantically closed or open, natural or artificial, etc.) in which it is expressed. Without arguing the point here, it should be noted that the kind of language chosen to express the theory has consequences for what can be asserted in the theory (i.e., it is generally not simply a matter of translating a theory from one language to another).

This leads to a second characteristic of theories--they assert something(s) to be true. A theory asserts that some state of affairs obtains. "Force is

equal to mass times acceleration." Or, "variations in the structure of a nation are related to changes in the nation's external environment." When sentences such as the above two appear in a theory (e.g., the second is in Rosenau's adaptation theory). I want to be able to say that it is being asserted to be true. That theories assert the sentences which comprise them to be true would seem to be fairly unobjectionable (for an opposing position see Friedman (1953), or perhaps, by implication, McGowan (1973)). To see this, one need only consider the alternatives. First, one might argue that theories assert nothing whatsoever. But then why do theory? Theories are (intended to be) collections of propositions (i.e., a certain kind of sentence)--not collections of nonsense. Second, one might argue that only some (perhaps none) of the sentences in a theory are asserted to be true, the rest are asserted to be false (or perhaps assert nothing at all). In most of its forms, this second position is clearly absurd. Rather than consider the more coherent variant here, let me simply say that in this paper all the sentences in a theory will be considered to be asserted to be true.

Note that to assert a sentence to be true is not to make it true. Whether a particular sentence is accepted as true will depend in large part on ones epistimological and methodological positions. These questions will not be considered here.

Having restricted a theory to being a set of sentences (in some language) which are all asserted to be true, let me make one more distinction. In this paper, I will be considering two senses of theory--a technical one and a non-technical one. In its technical sense a theory is a set of sentences asserted to be true which is closed under deduction, that is, the set contains any sentence that is logically implied by any other sentence in the set. This concept requires some preassigned logical framework or "calculus axioms"

(e.g., first-order predicate calculus). Any time we deal with an axiomatic theory, this technical sense is implied.

On the other hand, there is an important non-technical use of theory. A non-technical theory is simply a set of sentences asserted to be true. In this usage, no position is taken on the truth of any sentences "implied" by the theory sentences (indeed, "implied" may be undefined since no calculus axioms need be assigned the theory). Thus the entire body of knowledge about some subject may be referred to as the theory of that subject, as in "foreign policy theory." However, in this paper, unless otherwise specified, I will be using theory in its technical sense.

Having defined theory, it is important to provide a definition of a related and commonly encountered term--model. In very rough terms, a model is that "thing" which makes the sentences in a theory true. In theorizing we generally want to order or account for some aspects of a perceived reality. Thus we must first represent reality in terms of some posited objects and relations. Whether or not these posited objects and relations indeed represent reality is of course in many senses moot and is certainly contingent upon both our perceptual system and our ability to make and hold to distinctions.

However, a collection of objects and relations is a set theoretic structure and not a theory. We must write down some sentences describing (i.e., which are true of) this structure. These sentences I have termed a theory. The underlying structure I will call a model for that theory.

More specifically, a set-theoretic structure M is a set of elements (objects), $A = \{a_1, a_2, \ldots\}$, together with a set of relations of order i, $P_1^{i_1}$, $P_2^{i_2}$, . . . , and may be expressed

$$M = \langle A; P_1^{i_1}, P_2^{i_2}, \ldots, P_n^{i_n}, \ldots \rangle .$$

A formal language L in which properties of M can be expressed will consist of formulas generated by a specified set of rules, say the predicate calculus, from an alphabet consisting of relation symbols (R_1, R_2, . . .), variable symbols (x_1, x_2, . . .), connectives ($\neg, \vee, \wedge$ . . .) and quantifiers ($\forall, \exists$). Since functions and constants are special kinds of relations, function symbols (f_1, f_2, . . .) and constant symbols (c_1, c_2, . . .) will also be used in L. The language L will be assumed to be first order, that is, its variables range over the elements of A (as opposed to ranging over the subsets of A, or sets of subsets, etc.). Sentences in L are formulas containing no free variables.

Let T be a set of axioms in a language L. If φ is a mapping of constant symbols occurring in T into the set of objects A, and also a mapping of relation symbols occurring in T into the set of relations in M, then M provides an interpretation of T under φ. If this interpretation results in the sentences in T being true, then M is said to satisfy T and M is a model of the axiom set T. A model for a set of axioms then, is a set-theoretical mathematical structure which interprets the axioms in such a way that the axioms are true.

One of the most obvious problems with the above definition of model is what is meant by a sentence being "true." Rather than provide an extended discussion of truth, the reader is referred to Tarski (1944). The important question here is not how do we know whether a particular sentence is in fact true but rather what is meant by asserting a sentence to be true. This latter semantic question is treated in considerable detail by Tarski for important classes of formal languages.*

A (abstract) system may be defined as a collection of objects together with the relations defined upon them (Ashby, 1952). This definition is, of course,

---

* This discussion is taken from S. Thorson and J. Stever, "Classes of Models for Selected Axiomatic Theories of Choice" Polimetrics Laboratory Report, mimeo, 1973

the same as that given above for a mathematical structure. Thus it would seem that adopting a systems vocabulary for the ensuing discussion will not limit the range of theories which might be developed (or more precisely it will not limit the range of models we may theorize about).

From this perspective, a government (including the foreign policy making mechanism) might be viewed as an artificial system attempting to achieve various (perhaps poorly articulated and inconsistent) goals. At least part of these goals will have to be achieved in some outer (or task) environment. This outer environment may include domestic aspects of the "government's" nation as well as the rest of the "international system." Thus, I am arguing that a government can be viewed as a control mechanism and the rest of the world as the process being "controlled" by the government. This distinction immediately suggests several types of questions for the theorist. First, for particular nations, what do the inner and outer environments look like? Second, given an inner and outer environment, how can certain goals be "best" achieved? Third, given some set of objectives, what sorts of inner and/or outer environments can best achieve them? These are, of course, questions of description, policy, and design respectively. Since I will be arguing that these three may be ordered in the sense that answering policy questions will generally require having fairly good answers to the descriptive questions and that solutions to problems of political design will usually follow work in the policy area, I will treat each of these areas seperately moving from description through policy to design.

Description

I am using description here in a very general fashion to identify the standard concern in constructing scientific theory--to account for observations,

to identify interrelations among them and to predict new observations. I do not mean to take any particular metaphysical position on the possibility of knowing any external world (i.e., have the "correct" description of it). Rather, my use of "description" is meant to be similar to that of Wittgenstein's"*

> "That Newtonian mechanics can be used to describe the world tells us nothing about the world. But this does tell us something--that is can be used to describe the world in the way in which we do in fact use it."

The correctness of a description is measured in terms of the adequacy of its consequences and not in terms of some "intrinsic" correspondence to what really is. Thus the task of developing a descriptive theory of foreign policy behavior involves constructing a set of sentences which orders (makes sense of) some set of observations of foreign policy behaviors and which can be used to predict future foreign policy behaviors.

In achieving this goal the theorist will, of course, have to work on the basis of some finite number of observations. With these observations, he will be attempting to identify the underlying structure which is generating these observations. And yet, as is well known, there are an infinite number of structures which could have generated the observed strings of behavior.

More specifically, to describe a system is to write sentences which relate values of some variables to values of others. Assuming the system (i.e. model) is an adequate representation of the referrent reality, these sentences (i.e., the theory) can be used to predict future states of the world. As an example, consider the abstract system of Figure 1.

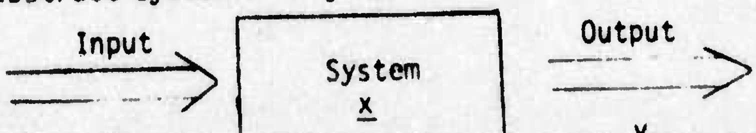


Figure 1

---

* Tractatus 6.342 ff

The state of the system at any point in time is given by the vector $\underline{x}$.

A description of this system might consist of the following equations:

(i) $\dot{\underline{x}} = f(\underline{x},\underline{u})$

(ii) $\underline{y} = h(\underline{x},\underline{u})$

These equations assert that changes in the internal state ($\dot{x}$) is a function ($f(\cdot)$) of the state of the system ($\underline{x}$) and the input ($\underline{u}$) and that the output of the system ($\underline{y}$) is a second function ($h(\cdot)$) of the internal state and the input. This is important for looking at the overtime behavior of a system (in terms of its outputs) it is crucial to look at internal state changes as well as input-output changes. In other words, output behavior need not be a function (in the mathematical sense) of inputs. The same input can lead to different outputs if the internal state* of the system is different.

As a highly stylized example consider the behavior of a "bully" nation. Suppose it is capable of being in only two internal states--it either is stable (S) or unstable ($\sim$S). Further, it is capable of emitting and sensing only two sorts of behaviors--aggressive (A) and non-aggressive ($\sim$A). Thus we have:

u: (A,$\sim$A)

y: (A,$\sim$A)

x: (S,$\sim$S)

Since the nation is a bully, it will behave aggressively whenever it can. And, as everyone knows, the only time a bully does not aggress is when it is threatened and in a weak (in our terms unstable) state. Thus we can write $y = f(x,u)$ as in Table 1.

---

* State here is being used in the sense of Ashby (1952) and not of Mesarovic (1970).

Table 1

Input (u)	State (x)	Output (y)
T	S	T
~T	S	T
T	~S	~T
~T	~S	T

As can be seen the output of the bully nation is entirely deterministic. Further, since even a bully gets nervous (and, therefore, unstable) when he is threatened, x = h(x,u) can be written as in Table 2.

Table 2

Input (u)	State (x)	New State (x)
A	S	~S
~A	S	~S
A	~S	S
~A	~S	~S

All this most likely seems both absurd and simple. However, further suppose a political scientist is watching the bully nation and trying to relate its behavior (outputs) to the behavior it receives (its input). What will he see?

First of all, he will generally ignore the internal system and simply relate inputs and outputs. Thus he might watch the bully over a long period of time and note that non-aggressive inputs always are followed by aggressive outputs on the part of the bully. However, he would note, threatening outputs are preceeded by threatening inputs only about one half of the time. Therefore, he writes an article in which he proclaims two general laws.

law (1) $P(y = A|u = \sim A) = 1$

law (2) $P(y = A|u = A) = 1/2$

Of course, by this time the world is getting rather sick of the bully's behavior and commissions our political scientists to recommend a policy toward the bully (this policy would consist of generating values of u). Given the two laws above, the optimal policy would, of course, be to always behave in an aggressive way toward the bully nation which would, according to law (2), guarantee that 1/2 of the bully's responses would be non-aggressive.

Note that our mythical political scientist, like so many of us, ignored the internal state of the bully nation. As a result, he was forced to state his laws in probabilistic terms and to conclude that the "best" that could be done was to reduce $p(y = T)$ to about one half.

However, by referring back to the transition tables, it can be seen that the bully can be made to act in a completely non-aggressive way. Suppose first he is initially in state $\sim S$. Then by always behaving in an aggressive way toward the bully, the bully will never respond in an aggressive way. If, on the other hand, he is initially in state S, then he will respond in an aggressive manner no matter what you do. However, by threatening him, you will force him into an unstable state and therefore continuing aggressive acts will result in no more threats from the bully. Thus, paying attention to internal states, it is possible to eliminate references to probabilities and to suggest a policy which will result in at most one aggressive behavior by the bully. While in this example ignoring internal structure did not result in "wrong" policy advice, it is possible to construct an example for which it would.*

---

* For example, see Kanter and Thorson (1972).

The important point here is that in developing descriptive theories of foreign policy behavior, we must pay close attention to the internal structure of the foreign policy generating mechanism as well as to that of the international environment in which the mechanism is imbedded. Specifically, it would seem important to look more closely at foreign policy bureaucracies. Examples of relevant work here include Ellsberg (1972), Niskanen (1971), and Halperin and Kanter (1973).

Policy

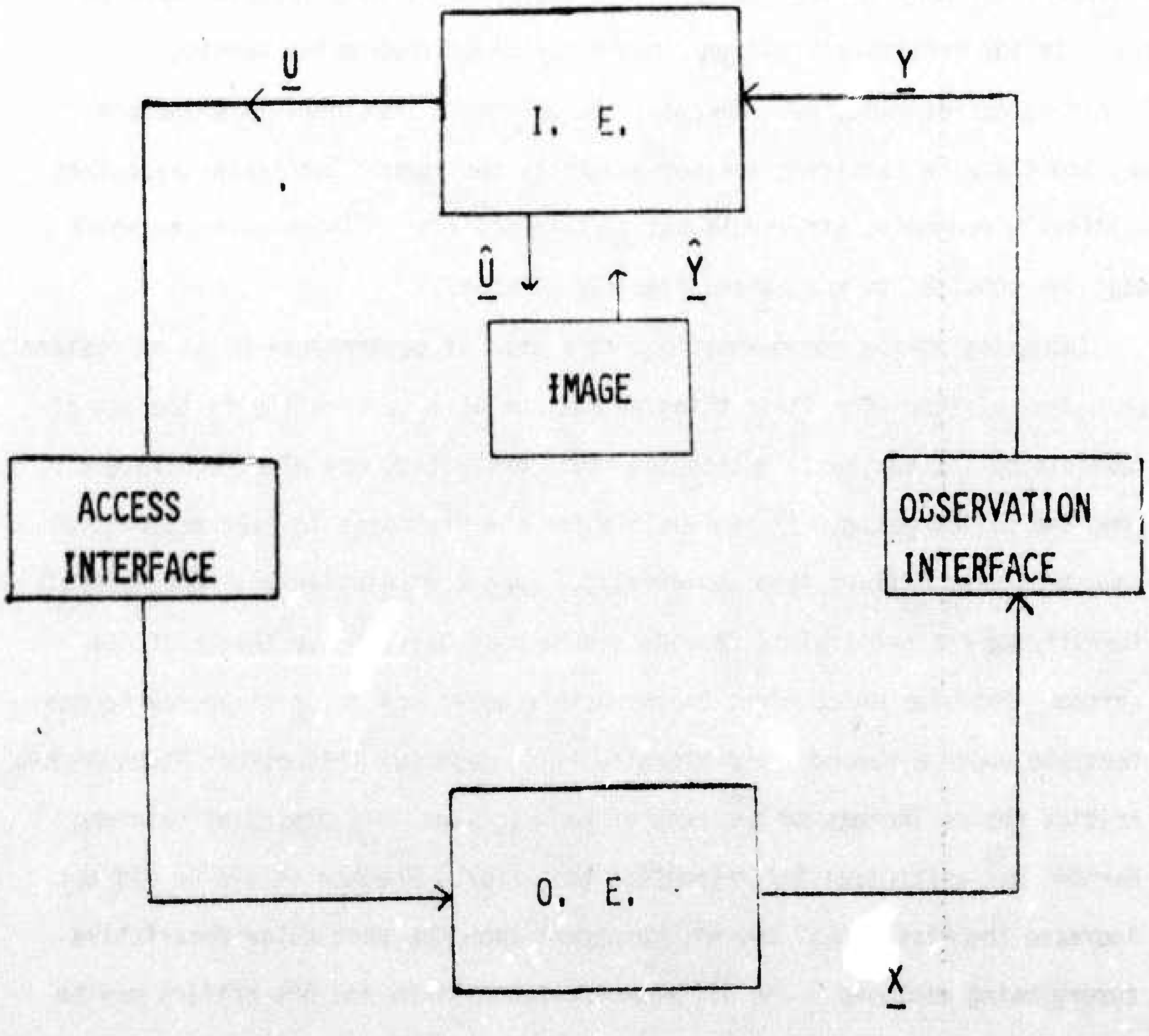
In the last section I alluded to the importance of descriptive theory in the making of policy recommendations (as well as in evaluating the impact of a policy). In order to make clear what I mean by a "policy," it is useful to return to the artificial systems structure of figure 2. The I.E. behaves in a way to maintain the states of the I.E. and the O.E. within some limits. These desired states can be termed goals of the I.E. in order to achieve its goals it sends outputs to the O.E.. These outputs of the I.E. are called the policies of the I.E..

If political scientists are going to be able to assist in consistently making "better" policy decisions, we must approach being able to do the following:

1) identify a set of feasible policies
2) identify the rules for linking policies to consequences
3) define a utility function over the various dimensions of the consequences
4) identify a rule for selecting a policy from (1) on the basis of (3).

Since the purpose of policies is to move the state of the entire system to some desired value (or set of values). It is important to recognize that goals are defined in terms of both the state of the I.E. and that of the O.E..

ARTIFICIAL SYSTEM STRUCTURE



This is different than the classical control problem where the goals is generally defined only in terms of the O.E..

Further, in order to identify the impact of a policy upon a system, it is necessary to first have a description of that system of the sort identified in the previous section. Such a theory will describe what happens when something is done to the system. But what can be done to the system? A U.S. President has many foreign policy options which are, in principle, open to him. In any particular instance, these may range from doing nothing to launching nuclear weapons. However, the options a President in principle has and those he considers are not generally the same. Constraints--be they political, economic, etc.--rule out certain policies. Those policies which meet the constraints are called feasible policies.

In making policy recommendations to a unit of government--be it a President or a desk officer--the first thing we must be able to identify is the set of feasible policy options. Notice too that constraints are often contingent upon the policy maker. It is feasible for the President to take actions not open to a desk officer (and conversely). Even the relatively simple task of identifying the constraints depends upon a good descriptive theory of the system. Policies which might be infeasible under one description may become feasible under a second. For example, it is doubtful that either Nixon or his critics desire increasing the risk of nuclear war. His mining of Haiphong Harbor was criticized for increasing that risk. Whether it did or did not increase the risk is, of course, dependent upon the particular descriptive theory being employed. The difference between Nixon and his critics may be viewed less as a disagreement about policy objectives and more as one over consequences of a particular policy. As we have seen, the predicted consequences depend upon the descriptive theory which is used to make the predictions.

Thus, the identification of feasible policies is not completely independent of the rules (i.e., the description) for linking policies to consequences. To do even the most simple part of policy analysis, adequate descriptive theory is required.

Having associated consequences with policies, we must then identify a utility function over their possible consequences. Such a function classically takes on scalar values. For example, consequences may be ordered purely in terms of their cost in U.S. dollars. In foreign policy applications it will not always be possible to define such a single valued utility function. The conditions under which a (real) single valued ordinal utility function exist are identified in Debreu (1954). It is a simple matter to show plausible situation (e.g. lexicographic orderings) which violate these conditions.

Therefore it will sometimes be necessary to look at multiple valued utility functions. This will be necessary, for example, when it is impossible to specify trade offs between dimensions of the consequences (as perhaps between "national security" and "international stability"). In such instances there are no general rules for ordering the consequences (for a survey of attempts see Roy (1971)). Which is bigger--the vector $\langle 9, 7\rangle$ or the vector $\langle 6, 10\rangle$? Thus a second problem we face in assisting in the making of foreign policy is dealing with multiple valued utility functions.

Even given a set of feasible policies and well behaved utility function over their possible consequences, the task of policy selection is not completed. Indeed the most important task remains. This is to define some sort of rule for selecting a policy given the utility function. Approaches to this question are reviewed in great detail by Chernoff (1954).

The point is that even if we know a particular actor's set of feasible alternatives and his utility function over their possible consequences, we

still cannot advise him how he should act. This can be seen more clearly if I first define a particular (though not unrealistic) sort of decision problem (one in which the descriptive theory is probabilistic). First define a set U^f of feasible policy alternatives $u_1, u_2, \ldots u_n$. Second, define the set S as the set of possible system states $s_1, s_2, \ldots s_m$ for the O.E. and the I.E. of the artificial system. Clearly the goal states s_i^* belongs to S. Finally we let the utility function,* T, be defined over S and U^f. Thus we have T (u_j, s_i). This looks more like a traditional decision problem if risk is seen as negative utility yielding a risk function $r(u_j, s_i) = -T(u_j, s_i)$.

The decision rule most often encountered in political science is that of maximizing expected utility. This criterion is a useful one if it is possible to accurately assign probabilities to states of the world. Here the task is one of multiplying $T(u_j, s_i)$ by the probability (p_i) of s_i for all u_j, s_i and then selecting that u_j for which

$$\sum_{i=1}^{m} p_i u_j$$

is at a maximum.

As an example consider a situation where the descriptive theory yield three possible states of the system each of which is equally likely $(p_1 = p_2 = p_3 = 1/3)$. Further there are two feasible policies u_1 and u_2. $T(u_j, s_i)$ are given as cell entrices in the following decision matrix:

	u_1	u_2
s_1	-30	30
s_2	3000	60
s_3	300	90

---

* This is a Von Neumann-Morgenstern utility function and is more restrictive than the ordinal utility index discussed by Debreu (1954).

The expected utility of u_1 is

$$1/3\ (-30) + 1/3\ (3000) + 1/3\ (300) = 1090$$

In like manner, the expected utility of u_2 is equal to 60. Under the maximize expected utility rule, policy u_2 ought to be enacted.

However this is not the only "reasonable" criterion which might be used. Another plausible one is to minimize your maximum risk. Remembering that risk is equal to negative utility, it can be seen that the maximum risk is obtained under u_1 (and is equal to 30). Thus the policy maker desiring to minimize maximum risk ought to enact u_2.*

There are many other equally plausible decision criteria which might be used. That there are such different functions is important since in risky or uncertain worlds, an actors' decisions cannot be predicted simply by knowing his feasible policies and the utility he attaches to their possible consequences.

It would be interesting to develop a classification of actors based, in part, upon the decision rule(s) they use in selecting foreign policy strategies. Perhaps, for example, leaders of nations with nuclear weapons would be more inclined to use a minimize maximum risk strategy than would leaders of other nations.

The importance of the decision rule being used cannot be overestimated. Even descriptive theories foreign policy decision-making are often dependent upon the particular rule being employed. Thus for example, a major source of disagreement between "quagmire" theories of U.S. involvement in Viet Nam (e.g., Schelsinger, 1968) and the stalemate theory of Ellsberg (1972) is over precisely the nature of the decision rule being employed.

---

* Ferejohn and Fiorina (1972) provide a very nice discussion of these two senses of rationality and their impact on people's voting.

In this section I have attempted to sketch out some minimal theoretical things we should be able to do before we can be of much use in giving policy advice. Further, I have argued that all of these things are dependent upon good descriptive theory.

Design

Whereas a policy problem (or, alternatively a policy theory) is concerned with identifying and implementing feasible strategies to meet some goal(s) in accord with a particular decision rule(s), design problems deal with identifying and describing various mechanisms (e.g., inner environments, outer environments, and interfaces) for the achievement of goals. The distinction I am making here between policy and design is analogous to the distinction between the values of variables (including parameters) and their structure. Policy changes are changes in the level of variables and design changes are changes in the structure relating the variables. Thus increasing the rate of an existing tax would be a policy change while introducing a new tax would be a design change.

The design problem is often viewed in engineering terms (Simon, 1969), where the problem is to design an inner environment (or control mechanism) which can achieve goals (or control) in a particular outer or task environment (process). It is important to notice distinction between the typical engineering approach to design and that being taken here. In engineering the process (or outer environment) is taken to be a given. For example in designing an airplane, the "laws" of gravity are fixed. The air frame designer is not free to design new gravitational laws which will make it easier for his plane to fly. This is not always true in designing social systems. Oftentimes the structure of the outer environment itself can be changed. Indeed it is sometimes "easier" to change the O.E. structure than it is to change the levels of various variables.

More generally, a task of design theories might be seen as one of identifying various governmental systems (including, of course, foreign policy mechanisms) which are effective in achieving specified goals in various classes of outer environments. If viewed this way, important tasks to be accomplished include developing taxonomies of outer environments and types of goals.

In designing these inner environments, one area which requires additional research is the interfaces between a governmental system and its outer environment. The governmental system can be viewed as a hierarchical information processor. This information is used to select appropriate outputs (policies). Implicit here is the idea that responses are functions of previous information and the present system state.

In order to receive this information the government (inner environment) must have some sort of observation interface. This serves as a perceptual system and determines what aspects of the outer environment the government will have information about. The observation interface may be thought of as a sort of screen which may modify and certainly blocks out some of the information in the outer environment.

The importance of the kind of perceptual screen used by the government is illustrated by the work in designing algorithms by which computers can play chess. The game of chess has been of special interest to workers in artificial intelligence for many reasons. First there has always been an aura of mystique about the game. To play the game at all, many people feel, requires a certain degree of intelligence and to play it at the level of the grandmaster requires real genius. Second, while chess is a complex game, the rules describing allowable moves are well understood. Third, the large number of possible moves creates the problem of sorting out relevant and irrelevant information. Fourth, since chess moves are made according to a well-defined sequence, the game is especially

tractable for playing on the computer. Last, it is felt that the principles necessary to the playing a good game of chess are similar to the principles necessary for dealing with other real world problems such as management and planning.

Shannon (1950) first identified the two approaches chess playing algorithms might take:

1. Scan all possible moves and construct a decision tree of equal length for each move (length here refers to the number of moves into the future the program scans). Then, using some weighting function the possible moves can be evaluated and the best one chosen.
2. Scan only certain moves. Eliminate others through the use of some special rule.

The first approach requires the computer to view the chess board in all its complexity. Very valuable information is treated the same as more unimportant information. The price of this synoptic approach is that, for a given memory size, the number of moves into the future that are looked at is severely limited. Much memory is wasted looking at trivial information. The second approach trys to avoid this problem. By pre-excluding weak moves a longer future can be considered. Unfortunately, the rule for eliminating bad moves is most difficult to discover.

The problem facing designers of chess playing machines was an interesting one. They had two approaches--one is easily implemented but rather wasteful, and the other is very efficient but extremely difficult to implement. A Russian grandmaster and electrical engineer named Mihail Botvinnik has spent considerable effort in trying to develop an algorithm for chess which is based upon the second

principle. Central to Botvinnik's algorithm is the concept of "horizon." At each half-move point the computer generates a mathematical "map" of the chess board. The horizon limits the area of the map scanned by the computer much as natural boundaries limit our horizon. "The horizon is the boundary of the region containing those pieces, and only those pieces, that can take an active role within the given limits of time for movement. ... An attack falling within the horizon is included in the mathematical calculations--otherwise, it is not."

Rather than having the machine calculate all positions and eliminate some very early, Botvinnik has developed a means by which the machine's perceptual system is designed to immediately eliminate (by not perceiving it) trivial information. This, of course, should greatly increase the depth to which moves within the horizon may be considered. Some sort of perceptual screen is important even in dealing with problems in which all information is, at least to some degree, relevant.

A less rigorous example of the importance of the observation interface can be taken from U.S. experience in Viet Nam. Ellsberg describes the usual Viet Minh and Viet Cong response to increased U.S. military intervention:

> After suffering initial setbacks they would lie low for an extended period, gather data, analyze experience, develop, test, and adapt new strategies, then plan and prepare carefully before launching them (1972, 120).

The U.S., however, monitored "enemy" strength through its field commanders who in turn equated frequency of enemy contact with enemy strength. If the enemy is strong, the reasoning went, then it will fight. If it is quiet, then it must be weak. Based on these reports, the tendency was always for the President

to view his policy changes as a "success." However, the U.S. observation interface was bad. Decreased contact did not mean a weakened enemy and, indeed, the periods of greatest crisis came at the times of highest U.S. optimism.

Included in this notion of an observation interface is, of course, some sort of social indicator system. Since no government can observe everything directly, it must develop some aggregate measures of performance in various areas.

As important as the observation interface is the access interface. How can actors in the government get their policies into the outer environment? There must be some structures involved with implementation.

Finally, the design theorist must develop means of characterizing various mechanisms and their effectiveness. How can the effectiveness of a particular mechanism be measured? I would think that here we are interested the competency of a mechanism to achieve certain goals in a particular class of outer environments. Competency, is not something that can be observed (though, of course, performance can). Indeed if the class of outer environments is restrictive, it is often possible to increase performance at the cost of decreased competence. Thus an important task for the theorist is to develop a way of characterizing the competency of a particular mechanism. My guess is that any definition of competency will be contingent upon the outer environment. A particular mechanism may be very competent over one range of environments and much less so over others. Therefore, in designing mechanisms, we must either have good estimates of future outer environments or else build in an effective self reorganizing capacity

At any rate, it seems to me that the development of design theory may well be a most exciting and important area for the theoretician. For it is this area which is, in my opinion, most lacking in concepts and programmatic guides to research.

References

Ashby, W.R. (1952) Design for a Brain, Butler and Tanner ltd.: Fromme and London.

Bailey, F. and R. Holt. (1971) "Towards a Science of Complex Systems." mimeo.

Bobrow, (1969) "International Indicators," paper prepared for delivery at the 1969 Annual Meeting of the American Political Science Association. Commodore Hotel, New York City, 2-6 September.

Botvinnik, M. (1970) Computers, Chess and Long-Range Planning (Springer-Verlag)

Chernoff, H. (1954) "Rational Selection of Decision Functions," Econometrica, 22, 4; pp. 422-443.

Debreu, G. (1954) Representation of a preference ordering by a numerical function, Chapter XI in R.M. Thrall, C.H. Coombs, and R.L. David (eds.), Decision Processes, New York, pp. 159-166.

Ellsberg, D. (1972) Papers on the War, Simon and Schuster: New York

Fogel, L., A. Owens, and M. Walsh, (1967) Artificial Intelligence through Simulated Evolution (New York: John Wiley & Sons, Inc.)

Formby, J. (1965) An Introduction to the Mathematical Formulation of Self-Organizing Systems (E. & F.N. Spon)

Friedman, M. (1953) Essays in Positive Economics, Chicago: University of Chicago Press.

Gregory, R. (1969) "On How so Little Information Controls so Much Behavior," in Toward a Theoretical Biology 2 (Edinburgh University Press).

Julez, B. (1971) Foundations of Cyclopean Perception, Chicago: University of Chicago Press.

Kanter and Thorson (1972) "The Logic of U.S. Weapons Procurement," Public Policy, Autumn, pp. 479-524.

McGowan, P. (1973) "Problems in the Construction of Positive Theories of Foreign Policy" in Rosenau, ed. Comparing Foreign Policies, Beverly Hills: Sage Publications.

Minsky, M. (1967) Computation Finite and Infinite Machines (Englewood Cliffs, N.J.: Prentice Hall).

Niskanen, W. (1971) Bureaucracy and Representative Government, Chicago: Aldine.

Rosenau, J. (1970) The Adaptation of National Societies: A Theory of Political System Behavior and Transformation, McCaleb-Seller, (New York).

Roy, B. (1971) "Problems and Methods with Multiple Objective Functions" Mathematical Programming, 1, 2, pp. 239-266.

Shannon, C., "Programming a Computer for Playing Chess," Philosophical Magazine, Vol. 41 (March 1950).

Simon, H. (1969) The Sciences of the Artificial. (Cambridge, Mass: MIT Press)

Tarski, A. (1944) "The Semantic Conception of Truth," Philosophy and Phenomenological Research, IV, pp. 341-375.

Tarski, A. (1966) Introduction to Logic, 3rd ed. Galaxy.

Simulated Foreign Policy Exchanges
The Rationale Underlying a Theory of Foreign Policy Interaction

Warren R. Phillips

and

Patrick T. Callahan

and

Robert C. Crain

Project for Theoretical Politics
Ohio State University

August 1973
Project Research Report No. 12

The research described in this paper was supported by the Advanced Research Projects Agency Contract No. DAHC 15 73 C 0197.

This article will present the underlying rationale for a theory of foreign policy dynamics, and is the first in a two part series which will attempt to specify a theoretical perspective for explaining foreign policy exchanges between nations. The goal of the first paper is to discuss the substantive thrust of the research, and to give an overview of the Monte Carlo computer simulation which lies at its core. The second paper will then present a formal mathematical theory which seeks to explain the foreign policy exchanges between nations.

Gradually over the last several hundred years it has become clear that the barrier to understanding foreign policy dynamics has not been the absence of important general concepts; rather it has been the difficulty in identifying and expressing that body of universal principles which explains the actions and reactions of nations in the international system. Most analysts agree upon the basic questions to be asked: Who are the relevant actors? What are their objectives? To what stimuli do they respond? How and why do things change? Halperin and Kanter point out that the differences between analysts over answers to these questions stem fundamentally from different perspectives. "The 'experts' cannot agree on what constitutes the most fruitful level of analysis or where best to look for answers" (Halperin and Kanter, 1973:1).

While not all foreign policy analysts have moved to an events data approach, many have chosen this source of information as a point of departure. In a review of the theoretical underpinnings of the events data movement (Phillips, 1973a), it was found that researchers in this movement have generated an almost overwhelming set of facts and

simple correlational findings. It is indeed unfortunate, however, that while overwhelmed by these fragments of knowledge we still have not discovered a way to structure this knowledge into a whole.

To learn structure is, in short, to learn how things are related. Jerome Brunner says: "Grasping the structure of the subject is understanding it in a way that permits many other things to be related to it meaningfully" (1960). An important question which must be answered at the beginning of any research endeavor is where the researcher should turn to identify the structure of the subject he is studying. It is our position that we must go to the mental images which each of us, as a student of foreign policy, has developed over a period of study. There is nothing new in returning to the mental structures we each hold in our heads in an attempt to explain foreign policy; J.W. Forrester has made this point repeatedly.

> Every person in his private life and in his community life uses models for decision making. The mental image of the world around one, carried in each individual's head, is a model. One does not have a family, a business, a city, a government, or a country in his head. He has only selected concepts and relationships which he uses to represent the real system. A mental image is a model. All of our decisions are taken on the basis of models. All of our laws are passed on the basis of models. All executive actions are taken on the basis of

> models. The question is not whether to use or ignore models. The question is only a choice between alternative models (Forrester,1971:54).

We seek to build on a body of research which has developed, over time, mostly out of the works employing events data. But rather than build an explanation of foreign policy dynamics piece-by-piece after each new analysis, we wish to attempt to assimilate that set of findings we currently believe to be essential and plausible into a single integrated theory.

The prevalent strategy in the events movement has been the delineation of a set of patterns for foreign policy actions (Rummel, 1965; McClelland and Hoggard, 1968) and the subsequent search for other variables which correlate highly with these patterns. The principal characterization of this movement has been the collection of data with a view to identifying the dispositional characteristics of nations as they interact in both normal times and crisis periods. Unfortunately, Brunner (1970) has demonstrated very convincingly that data analysis strategies presently employed by political scientists (such as correlation and regression analysis) will usually not reveal the underlying structure of the theoretical system. This will be the case regardless of whether the systems are analyzed cross-nationally at a point in time or individually in a time series. Thus, there is a very serious data analysis problem to be faced in events interaction theorizing. To what extent can data--even time series data--be used to identify the basic structure of a theory of international interactions? Since most analysts' strategies cannot be used to distinguish between the structure of a theory and the para-

meters of that theory, it is the responsibility of the analyst to impose the basic structure on his observations prior to statistical manipulation.[2] Cain and Watts point out that, without a theoretical framework to provide order and rationale for large numbers of variables, we have no way of interpreting the statistical results: "Regression and correlation analysis is properly used to estimate parameters for a model only when the structure of that model and the elements which make up that theory are already well specified. The specification of the structure must precede the application of statistical techniques" (1970: 229).

We have chosen to specify the structure for a theory of foreign policy dynamics based upon the cumulative analysis that we and others have done and upon what we consider to be substantively plausible assumptions. It should be noted that there are others among us who prefer other strategies. Indeed, many would disdain any "premature" attempt at formalization. We are sympathetic to these arguments and do not advocate that our approach be accepted to the exclusion of other approaches. In addition, it should be pointed out that arguments about how to proceed deal with the context of discovery and as such are not open to support from the philosophy of science. Only the context of justification is dealt with in the philosophy of science.[3]

MAJOR ASSUMPTIONS

Underlying our approach is the intent to specify how national decision-makers tend to select types of action and reaction from a repertoire of foreign policy outputs to meet different kinds of routine

and non-routine international situations In order to build our theory we have found it necessary to make the following assumptions:

1. The making of a foreign policy can be conceptualized as a series of decisions made by national officials. Foreign policy activity consists of the discrete behaviors representing the outcomes of these decisions.
2. Foreign policy can be operationalized as the aggregation of the foreign policy activity (behaviors) according to some logic imposed upon them by the actor and/or observer.
3. The behavior of one actor towards another is responsive to the actions of other nations and involves efforts to influence who the leaders of these nations will be, what decisions they will make, and how they will define the relations between their nations and others.
4. Foreign policy is made in a multi-nation environment by decision-makers who have to cope with domestic constraints and who have mixed desires (or goals). Their activity is essentially a process of adaptation to the external and internal environments (which they seek to coordinate in an effort to maintain autonomy and national sovereignty while pursuing positive goals in the international system).

The question now becomes one of where to turn to find suggestions for making more formal explanations of the analogs used by nations to

match outputs to inputs. We need a scheme for tying together the rich substantive conclusions from the events literature.[4]

A general scheme suitable for our purposes has been fashioned from work in information theory and in cybernetics, and has been used, with variations, by a number of international relations scholars (Deutsch, 1953; McClelland, 1967; Phillips, 1973c). Two ideas central to this approach are of primary interest here. The first is that each action of a nation can be considered as a potential piece of information that may communicate the intentions, desires, or dislikes of the actor nation to other nations. Information theory may thus be brought into the analysis of the international interaction process. The second idea involves the treatment of social entities (such as nation-states) as purposive systems, and the application of knowledge from the fields of cybernetics and control theory.

Purposive systems are characterized by the pursuit of a goal, and by a process of steering (toward the goal) based upon information concerning any discrepancy between the system's current position and its desired goal (feedback). Thus the system alters its behavior, on the basis of information about its past performance, in order to better achieve some desired goal or end state (Deutsch, 1968; Wiener, 1950).

It is crucial to understand that steering must be with reference to both a purpose or a goal and an evaluation of previous successes and failures through the mechanism of feedback, for such an understanding leads to a number of important points. First, the goal situation sought is outside the system and deals with the <u>purposes</u> of the state in exchanges with other nation-states. Second, the system itself is not

isolated from its environment but depends for its functioning upon a constant stream of information from the environment (as well as upon a constant stream of information concerning its own performance). Finally, a nation's goals may be changing over time. Burton (1969:10) argues that states as political systems operate within an environment of other states to which they are adapting and responding. National interests are not restricted to fixed goals; they include successful adaptations of these goals (a process).

It is also important to realize that the notions of adaptation and steering themselves imply that actions must be based in part on the expectations (of future response) gained from past experience in dealing with an environment which most certainly can be differentiated into objects and behavior. Holsti, North, and Brody share this view:

> Essentially, then, it is by projecting past experience into the future that human beings make decisions; and statesmen, in this respect, are not exceptions. Foreign policy decisions, like other human decisions, imply not only an abstraction from history, but also the making of "predictions"--the assessment of probable outcomes. These two operations may be undertaken almost unconscioulsy, but they are nonetheless real and inescapable. The Marshall Plan was based upon a prediction, derived from some combination of experience, that systematic aid to European nations would bring about certain consequences. Viewed in retrospect, this prediction

> seems to have been generally sound. The basic prediction inherent in Khrushchev's decision to establish long-range missiles in Cuba, on the other hand, was much less accurate (1968: 125).

However, before the reader can see the theoretical fruit which the scheme just discussed will bear, we must ask him to bear with us while we examine a substantive area which is strongly related to the later theoretical development. The area to be examined deals with a concept generally called "reciprocity," and it is important for two reasons. First, a good deal of work has been done involving the reciprocity concept, and the work has been generally well received. Second, we feel that our model takes an important first step toward explaining why various patterns of international behavior have been reported in that literature, and why different patterns may occur at various times and under varying circumstances. In a very real sense, then, we hope both to offer additional support for reciprocity and to go beyond it in terms of theoretical development.

RECIPROCITY

A good deal of work has already been completed on specifying relatively simple automatic reaction models. This idea was first suggested by Dean Pruitt (1969:392-3) with the introduction of the concept of reciprocity.[5] "Change in one party's level of output on a given dimension often produced reciprocity (also called reciprocal change), i.e., a resulting change in the other party's level of output

on the same <u>or another</u> dimension. [Emphasis ours: note that in order to be considered reciprocal, in this usage, behavior need not be of the same type or magnitude as that received.]

There are a number of reasons why we expect that reciprocity would be a powerful concept for explaining the interactions between nations. One is that there is a very general tendency for humans to respond in a manner similar to the behavior they are confronted with. Some of this tendency would be expected to apply to the behavior of foreign policy decision-makers. In addition to this, though, there are rational reasons for foreign policy makers to initiate behavior which reciprocates the behavior received. If the behavior being responded to is a cooperative action, then a cooperative response would be appropriate because it would reward the sender of the cooperative action (and thus increase the probability of future cooperative behavior). Also, failure to respond with a cooperative act when it was expected may cause the beginning of a series of conflict behaviors.

If the behavior to be responded to is conflictual, it may very well be a challenge to some concrete national foreign policy objective. If this is so, the foreign policy makers can be expected to respond with conflictual behavior in an effort to influence the other party to stop in its challenge to the national goal. It has been argued that nations <u>ought</u> to respond to a challenge to their national objectives with conflictual responses if they want to protect these objectives (Schelling, 1960).

It should be noted that in a significant sense <u>any</u> violent conflict behavior constitutes a challenge to national objectives. One fairly general national objective is to minimize the amount of

violence received from other nations in the system. Thus, any violence directed at a nation ought to be responded to with behavior which would deter such action in the future.

The concept of reciprocity has a long history in writings on international relations. Recently several theorists have emphasized the importance of considering the interactive aspects of behavior exchanged between nations; this is especially important when the nations are antagonists. For instance, Burton (1968) asserts that the progression towards war depends upon equal contributions from both sides, each being governed by perceptions of threat. North and his colleagues assert that war may occur in any number of ways, but the chances of its occurrence are increased by the hostility in the atmosphere of crisis generated by the joint exchanges of the parties involved (1968). Zinnes has been concerned both with the expression of hostility and with its perception as expressed in the ensuing responses to that hostility (1968). These authors all discuss a process of exchange that underscores the similar importance of both participants and actions.

Moreover, the concept of reciprocity has been shown to have some empirical import. Statements developed from the reciprocity perspective along the lines of "behavior begets behavior" have been tested by the principal author and others and found to have a great deal of predictive power (Phillips, 1971; Phillips and Crain, 1972; Tanter, 1972; Bartos, 1966; Azar, 1970; Smoker, 1969; Leng, 1972).

The problem is how to couch the reciprocity concept in a language structure which will enable us to build a simulation on it. Specification of that language is largely provided in the next section.

LEARNING

In order to build a simulation which will produce patterns of international behavior marked by reciprocity between nations, we have found it useful to turn to mathematical learning theory. The use of learning was clearly presaged earlier when we indicated that discussions are made partly by projecting past experience into the future. Decision-makers internalize certain lessons through experience; such internalization is learning. Thus there is a very natural bond between reciprocity and learning which we wish to exploit.

The modern perspective in mathematical learning theory began about 1950, and was initiated by the stochastic learning theory of Robert Bush and Frederick Mosteller (1951, 1955). The process considered by Bush and Mosteller involved a sequence of discrete events. Each event consisted of the presentation of a stimulus to which the subject responded (by selecting one from a set of alternative responses in accordance with an associated set of probabilities). The response was followed by an outcome which might induce changes in the probability values before the next trial. Thus, the learning process was analytically divided into a sequence of stimulus, response, outcome, and resultant probability adjustment. All models in mathematical learning theory are concerned with describing this flow of (or change in) probability from trial to trial and the resulting sequence of distributions.

One of the most applicable developments of the Bush and Mosteller model has been suggested by Rainio (1966). Rainio's basic idea for constructing a stochastic model of exchanges was to consider social interaction as a process derived from the learning of individuals participating

in it. The fundamental assumption underlying his model is that a sequence of behavior is a series of choices among various alternatives. Certain probabilities are associated with the choice of the behavior alternatives in accordance with the mathematical laws developed by Bush and Mosteller.

The core of the system is an adaptation process, a theory of social interaction that adjusts the probabilities of interactions and behavior based upon an assessment of past interaction. If an exchange of acts is assessed as rewarding then the probability of this action being repeated is increased. In like manner, one punishing exchange will decrease the probability of recurrence. One purpose of this model is to find, in each particular instance, the probabilities that a particular actor will choose a particular behavior and direct it toward a particular target.

The reader will recall that in the earlier discussion of the purposive characteristic of social systems it was argued that it is necessary to have goals before behavior can be modified to reach them. We believe that there are two goals which nations can pursue which will produce patterns of behavior marked by high reciprocity.

The first such goal was the one employed by Rainio in his development. It is that social entities seek consistent relations. When a relationship is consistent then it is rewarding to a nation which has consistency as its goal. For example, if two nations were to engage in mutually conflictual behaviors, then the exchanges would be consistent and hence rewarding. That this goal will generate a

pattern of behavior marked by reciprocity is clear and need not be commented on further.

The second such goal is probably more prevalent in international politics. That goal is that nations seek to minimize the amount of conflict and maximize the amount of cooperation directed at them by other nations. Thus when an interaction stimulates a cooperative response from the partner it is rewarding and when it stimulates a conflictual response it is punishing.

Earlier, in discussing the strategic reasons for nations to behave reciprocally, the argument was advanced that in effect reciprocal behavior would be an outcome of a national foreign policy which sought a) to minimize conflict received by punishing those who send conflict and by rewarding those who send cooperation, and b) to maximize cooperation received by rewarding it when it occurs. Thus the second goal will generate reciprocal patterns of behavior.

In order to realize either of these two goals, nations can employ two different strategies. One strategy would be to interact more with those partners who are in the desired posture towards oneself. Thus, if one wants only consistent relations, then one will increase behavior initiated towards nations which respond consistently to one's behavior. If, for example, one wants cooperative relations, then one would increase behavior directed towards nations which are predominantly cooperative with the actor.

The second strategy involves attempting to get those nations who are not responding in the desired fashion to change their behavior. In other words, one tries to persuade them to change by increasing the

amount of behavior aimed at them.

The predictions generated by the two goals and two strategies for different patterns of interaction in a dyad are laid out in Table 1. As can be easily seen, the predictions for the second strategy are completely different from those for the first strategy for all cases.

All of this substantive discussion allows us to stipulate the first fourteen of the simulation rules which constitute the essence of our theory.

Rule 1. International interaction takes place between two nations in a given finite set of nations.

Rule 2. Interactions are capable of a strong chronological order.

Rule 3. There is a probability vector, independent of time, whose components specify the probability that a specific number of acts occurs in the system during one time period (month).

Rule 4. There is a probability vector, independent of time, whose elements give the probability that each nation is the actor. The probabilities in the vector sum to unity.

Rule 5. For each nation there is a probability vector (not necessarily independent of time) whose elements give the probability that a nation, as actor, contacts each of the other nations. There is one such vector for each nation and the probabilities in each vector sum to unity.

Rule 6. Once the actor and object are specified the contact is always realized.

Rule 7. A nation must desire one of two possible modes of interaction (goals). It may seek consistent relationships with its dyadic partners or it may seek cooperative relationships with its dyadic partners.

Rule 8. A nation must choose one of two strategies in seeking its goals. It may choose to increase the probability of interacting with those partners with whome interaction is the desired mode (reinforcement) or it may choose to increase the probability of interacting with those partners with whom interaction is not in the desired mode (conversion).

Rule 9. When contact is realized between two nations the object perceives the behavior as rewarding or punishing. The behavior is rewarding if it places the interaction in the desired mode. The behavior is punishing if it places the interaction out of the desired mode.

Rule 10. If j wishes to <u>increase</u> its probability of choosing i as object the next time j is the actor, it does so according to the rule $P_{N+1} = P_N + \alpha_0 (1 - P_N)$. The probabilities of j choosing other nations as objects will then be decreased so that the result is still a probability vector whose elements sum to unity.

Rule 11. If j wishes to decrease its probability of choosing i as object the next time j is the actor, it does so according to the rule $P_{N+1} = P_N - \beta_0 P_N$. The probabilities of j choosing other nations as object will then be decreased so that the result is still a probability vector whose elements sum to unity.

Rule 12. For each dyad, and for each specific type of behavior which i may send to j, there is a probability vector (not independent of time) each element of which specifies the probability that j will respond to i with a particular type of behavior the next time j is the actor and i the object.

Rule 13. If the action sent by i to j is rewarding to j, then j will increase the probability of acting in the same way as its most recent action toward i. This increase in probability follows the rule $P_{N+1} = P_N + \alpha_a (1-P_N)$. The probabilities of choosing the other acts in the vector will be decreased so that the elements of the vector sum to 1.0.

Rule 14. If the action of i toward j is punishing to j, then j will decrease the probability of acting in the same way as its most recent action toward

i according to the rule $P_{N+1} = P_N - \beta_\alpha P_N$. The probabilities of choosing the other acts in the vector will be decreased so that the elements of the vector sum to 1.0.

The basic goal of the simulation model described is to increase our understanding of foreign policy decisions by linking together some of the principal factors involved. In attempting to develop a greater degree of knowledge about the interaction of nations in the international system, we consciously strive towards an explanation of the mechanisms which produce interactions. We would expect that the interaction between nations is influenced by a wide variety of considerations. Mathematical learning theories of Bush and Mosteller were adapted by Rainio and have been carried here into international relations as a mechanism for matching inputs to outputs. They provide a pleasure-pain learning algorithm. However, international relations is generally considered to be much more complex than this view of reality would suggest. We intend to add complexity to this basic model in an attempt to integrate into the model a number of other concerns found in the foreign policy literature.

UNCERTAINTY

Earlier, we posited that the behavior of one nation toward another nation is in large part dependent upon the behavior of that nation to it. The idea of a chronological order is also important and closely related to the concept of interaction. If a nation's behavior

or choice of object is in any part determined by behavior it has received, it is logical to expect that the order in which actions are received and sent will be an important consideration. Similarly important is the question of volume (or variety) of interactions. It would seem that the more interactions of a specific nature are received the more established is the pattern of interaction between two nations. There is, in other words, very little uncertainty, but a change in the nature of the interactions would add uncertainty.

The amount of information being conveyed between nations in any period of time must depend upon both the number of signals transmitted from nation to nation and the variety of those signals. Techniques have been developed to measure and account for both the variety of signals transmitted and the amount of information transmitted. The heterogeneity of these signals--that is, the variety of basic patterns--at any point in time is a measure of the uncertainty which would attend any attempts to specify the sender's selection process (Cherry, 1957; Shannon and Weaver, 1949; Ashby, 1952).

Information theory provides an excellent measure of the uncertainty H, present in a set of signals:

$$H = \sum_{i=1}^{N} - P_i \log_2 P_i \ ,$$

where P_i is the independent probability of occurrence of signal type i and hwere there are N types of signals. Thus, from the probabilities P_i of different types of signals occurring in a given time period (in this case, that defined by the last 8 acts received by the object), the uncertainty associated with the score for that period can be ascertained. If all outputs are equally likely, uncer-

tainty is at a maximum. It is common to divide the actual uncertainty by the maximum potential value, deriving as a result the percentage of (maximum) uncertainty (H_{rel}), which is more easily comparable across sources with differing sets of possible signals.

Let us consider two examples. First, there is the case in which a given nation chooses to send to a particular object 8 acts in a given time period. The distribution of these acts is presented in Table 2; notice that the actor has chosen to send an equal number of each type of signal to the object. By way of contrast, Table 3 shows an unequal distribution of actions across the same eight categories. Observe that the relative uncertainty figure for the distribution in Table 2 is higher than that for the distribution in Table 3. Thus, the implications of uncertainty are that in the equal-probability instance, there is no way to judge if further occurrences would be more likely to fall in one category instead of another. In the case of Table 3, we might expect that the object nation would be more likely to receive act types D and E than the other acts. Thus an observer's uncertainty as to the likely activity of the nation represented in Table 3 is reduced. The smaller the H_{rel} figure, the more certain it is that a nation will choose a particular activity. McClelland has interpreted this relative uncertainty by suggesting: "A common sense way to view a series of H_{rel} numbers us to think in terms of a 'fanning out' toward equality of distribution across the category system with the larger figures and a 'channeling in' of the distribution towards relatively frequent occurrences in fewer categories with the smaller figures. As the ratio approaches 1.00 it suggests not only that everything that

could happen has been occurring but also that the behaviors have shown increasing signs of disorderliness. The information measures do not tell us what the particular lack of ordering is but they do give us a technical indication of a large amount of variety in the emissions. As the ratio decreases towards .000, the suggestion is that (1) there may be present a large amount of highly patterned and repetitive behavior and a limited variety in the actions or (2) very little is occurring" (1973:91).

A long series of analyses by Charles McClelland and his associates (1965, 1968, 1973) have been carried out with the variety measure introduced above to establish how it functions in crisis and non-crisis periods. They have demonstrated that the mix of behavior does indeed change toward greater variety in a crisis. The basic results are these: (1) With occasional exceptions, an H_{rel} of .700 or higher is associated with crisis periods and only with crisis months. (2) If we operationalize the beginning and duration of international crises with an H_{rel} criterion of .700 or higher, we are able to state when a particular crisis began and how long it lasted. (3) All non-crisis periods, with rare exceptions, have monthly H_{rel} figures below .700 (McClelland, 1973: 92-93). The literature on communications in international relations argues that in periods of crisis overload occurs, and actors display an inability to respond consistently to foreign policy inputs (Holsti, 1965; Burton, 1968). This would suggest that for dyads in periods of high relative uncertainty (usually crises) nations are less able to respond consistently to their object nation's activities. But it seems to be

the case that in periods less uncertain than crises, nations are capable of responding more reciprocally when they know more fully their opposite's intentions. This point needs further elaboration.

Burton has suggested that if one of the "tricks" in negotiation is for actors to send frequent responses if they wish to communicate changes in their perception of the situation. He also suggests that the process of conflict resolution is in part a process of testing whether information is received as it was transmitted (Burton, 1969: 54-55). One function of ambiguity and noise in message signals sent from one nation to another, as pointed out by Jervis, is "to make it easier for actors to strike and maintain bargains. At first glance the contrary argument seems more plausible--that the easier it is for each side to make its views understood (at least on the semantic level), the more the bargaining process is facilitated-- . . . this position might be correct if the actors could make the other side believe they would act the way they said they would" (1970:127). But since this is normally impossible, noiseless bargaining would make simple initiatives less plausible and thus more likely to be discounted.

When nations are sending multiple types of signals it would appear easier for other nations to respond with what they judge to be appropriate behaviors. This is so because multiple types of signals allow a nation to test whether its intent was correctly received by analyzing the multiple responses. It is also likely to be the case that if one nation wants the other to believe its intent, that nation should signal its intent in multiple ways (by orchestrating its signals).

Nations which are interacting frequently must consider <u>how</u> they can make other nations understand the intent of their communications. If a nation wishes to orchestrate its foreign policy outputs to facilitate understanding:

1) It must design and deliver messages in a way that will gain and hold the attention of the intended object.
2) The signals must adequately refer to past experience between actor and object.
3) The communicator must choose actions which match his verbal statements so that the message is convincing.
4) The communicator must be able to notice and interpret any responses either as feedback or as the performance of preferred behavior before he can estimate his degree of satisfaction (as measured against his country's objectives).[6]

Now let us summarize this discussion. When single signals ($H_{rel} = 0$) are sent, they are likely to elicit only moderately standard responses. Slightly more complex messages (with a relative uncertainty value greater than zero but less than 0.5 for any given period) are somewhat more easily responded to in a systematic fashion. On the other hand, those messages which are quite heterogeneous in the number of signals sent (but short of the complexity facing crisis participants) can be responded to clearly and consistently.

This leads to the following assumption:

Provided that the communications channel is not overloaded, the more heterogeneous the signals

sent from one nation to another in a given time period, the more certain are observers in specifying an appropriate response.

Extrapolating from this discussion, let us suggest that when there is a homogeneous signaling from one nation to another (that is, when the redundancy in signals is high) one would expect the recipient nation to identify less clearly the intent of the actor and to act out of its own inertia. For periods of time in which there is a heterogeneity of signals (behaviors), and thus a richer mix of behavior for that time period, objects are more certain about the implications (real and potential) of the actor's behaviors. This allows us to add another rule to the simulation model:

Rule 15. If the relative uncertainty (H_{rel}) computed on the last eight acts sent from i to j is less than .50, then α_o, α_a, β_o, and β_a are decreased by $k_{\alpha o}$, $k_{\alpha a}$, $k_{\beta o}$, and $k_{\beta a}$ respectively. If H_{rel} is between .50 and .70, then α_o, α_a, β_o, and β_a are increased by $k_{\alpha o}$, $k_{\alpha a}$, $k_{\beta o}$, and $k_{\beta a}$ respectively. If H_{rel} is greater than .70, the probability of nation j choosing nation i as object is increased in accordance with the rule $P_{N+1} = P_N + \alpha_o (1 - P_N)$, and then α_o, α_a, β_o, and β_a are decreased by $k_{\alpha o}$, $k_{\alpha a}$, $k_{\beta o}$, and $k_{\beta a}$ respectively. [See also Rule 18.]

DOMESTIC CONSTRAINTS

Few political scientists would dispute that governments are required to deal, on a continuing basis, with large numbers of problems of many different types. In order to cope with these problems large organizations are established, usually along functional or quasi-functional lines. Such organizations routinize as much of their activity as possible through the development of a set of <u>standing operating procedures</u> (SOP's).

In order to minimize demands on their time, top government decision-makers focus their attention primarily on problems which percolate up to them through these functional organizations, make decisions on those problems with information transmitted through the same organizations, and rely once again upon the organizations to carry out whatever action has been chosen as the appropriate response. In this form of decision-making there is a strong emphasis on two points. First, the organizations involved are considered to be hierarchically structured. Second, only very limited flexibility is available to the agency in performing any of its functions; the SOP's form relatively tight constraints.

Foreign policy outputs are thus always regarded as the result of ponderous procedures developed over time, but instead are sometimes regarded as outcomes of a political process in which individuals (usually the heads of organizations) engage in compromise, coalition formation, competition, and bargaining. Goal-setters resort to such activities in efforts to influence the selection of policies and actions which

are judged favorable to the individuals and to their respective agencies according to personal and organizational criteria. Furthermore, while this bureaucratic politics scheme assumes that the organizations themselves are hierarchically organized, it also assumes that goal-setters have sufficient freedom of maneuver on various issues to enable them to actively pursue a political, bargaining-oriented strategy in inter-agency disputes during policy decisions.

Of course, a distinction is made between actions taken by the bureaucracies (in accordance with SOP's and previous policies) and actions taken as a result of political interaction among goal-setters. While much of the day-to-day interaction among nations is handled by the former level, it is suggested that really important decisions are either kicked up to, or sent up at the request of, the high-level officials.[7]

We wish to focus here essentially upon a combination of these characteristics. It is clear that organizational structures play a large part in foreign policy. In the SOP case they are the primary focus. In what has become known as the bureaucratic politics paradigm they form the context within which individual goal-setters, as well as lower-level bureaucrats, are seen to function. We should remember, however, that organizational structure and SOP's are considered to be only two of a larger and relatively diverse set of influences upon goal-setters.[8]

The general utility of the bureaucratic politics paradigm as a means of explaining foreign policy decisions and actions has been

well demonstrated (Halperin, 1972a;, 1972b; Neustadt, 1970; and Halperin and Kanter, 1973, editor's introduction). The paradigm itself has been given additional refinement in efforts by Allison and Halperin (1972), and by Halperin (1971).[9]

A close examination of the bureaucratic politics paradigm shows that one of the paradigm's dominant features is a distinction between those actions taken by lower level bureaucrats (workers) and those actions taken by goal-setters. Outputs generated at the worker level can be treated as resulting from SOP's which have developed slowly and incrementally through time in a learning process. When goal-setters become involved, however, the learning process undergoes significant changes. In general, we might expect that the process of adaptation takes place much more quickly when senior level decision-makers determine foreign policy outputs, since they are much less tightly bound by SOP's in general, and by organizational constraints on specific issues. It also seems reasonable to expect that during high-threat situations (such as crises and military conflict situations) goal-setters are considerably more likely to involve themselves in the foreign-policy process. Finally, various domestic (political) considerations would probably influence goal-setters' decisions on whether or not to intervene in specific policy decisions; thus the role of domestic events will be considered in more detail shortly.

With respect to bureaucratic politics, then, it seems most important as a first cut to distinguish simply whether or not foreign policy outputs are the result of goal-setter involvement in the decision process. If only workers are involved, reactions to various types of situations will be quite stable, and will change only slowly and

incrementally. When goal-setters determine outputs, however, relatively major shifts from SOP's are possible and thus learning can be quite rapid. The greatest problem remaining is thus to specify when goal-setters are likely to involve themselves. We have suggested in the section on uncertainty that such involvement should take place during periods of crisis, and during periods of military conflict.

These thoughts are reflected in the following simulation rules:

Rule 16. There is a probability vector, not independent of time, each element of which specifies the probability that a particular level of foreign policy decision-maker chooses a nation's action. There are two levels of foreign policy decision-makers: goal-setter and working operator.

Rule 17. If goal setters are involved in the choice of an action, then α_a, α_o, β_a, and β_o all increase by $\ell_{\alpha a}$, $\ell_{\alpha o}$, $\ell_{\beta a}$, and $\ell_{\beta o}$ respectively.

Rule 18. If H_{rel} is greater than .70 for behavior sent from i to j, the probability of j's goal setters being involved in choosing j's next action to i will be increased in accordance with the rule $P_{N+1} = P_N - \alpha_b (1 - P_N)$.

Previous work by the principal author (Phillips, 1973b) has suggested that the influence of domestic events may be greatest in determining the degree of a nation's over- or under-response from a relatively stable pattern. A consideration of domestic events in

this manner fits nicely with the analytic approach of treating domestic activity as an important determinant of whether or not goal setters become involved in the foreign policy process. It was suggested earlier that it is the involvement of such senior-level officials that is responsible for significant shifts away from reasonably stable norms of foreign policy behavior. Within this section, then, we shall also be concerned with suggesting what broad categories of domestic activity might be important to goal-setters, and with suggesting further what the effects of each category might be with respect to the foreign policy process.

Very broadly, we can classify domestic activity into three types: renewals of power, transfers of power, and indications of domestic uncertainty. The first type, renewals of power, refers to reelections of regimes already in power. Such reelections could be either victories at the polls (in western-style democracies, especially), or expressions of support of an equivalent nature (the election of new members to the Politburo who are known supporters of the current regime, for instance). As expressions of support, events of the power-renewal type should encourage a regime to continue most of its current policies, and (for a time at least) to have less fear of the potential consequences arising from discontinuing unsuccessful policies. It does not seem likely, however, that renewals of power, of and by themselves, would significantly alter the propensity of goal-setters to be active in the foreign policy process.

Power transfers would include dismissal and replacement of the current regime, and would usually reflect a lack of support for that regime's policies. In general, we might reasonably expect members of the new regime to participate actively in the determination of foreign policy, in order to bring it more nearly in line with their own goals. Thus the opportunity should exist for rapid learning and for major shifts from previous positions.[10]

The third category, indications of domestic uncertainty, can be subdivided according to whether the expression of uncertainty concerns foreign or domestic affairs. A regime faced with uncertainty as to whether its foreign policy activities will engender popular support or popular animosity will likely choose to participate actively in the selection of foreign policy outputs, and will also be quite sensitive to whether its chosen outputs are rewarding or punishing in terms of the regime's goals.[11] If the regime is faced, on the other hand, with the potential loss or gain of a significant amount of support as the result of its domestic policies, it is probable that the regime will concentrate on those domestic policies and on the domestic policy process. Such concentration will result in a lack of attention, on the part of senior officials, to problems of foreign policy. In addition, the demands of domestic uncertainty may cause goal-setters to direct the staffs of agencies whose responsibilities bridge both domestic and foreign affairs to concentrate on the domestic area.[12] This results in a diminished overall capacity for learning (and even incremental adjustment) within the foreign policy process; previously established SOP's and other norms are likely to dominate foreign interaction under such circumstances.

The impact of domestic events upon the dynamics of foreign policy has been specified in the simulation through inclusion of the following epic rule:

Rule 19. Domestic events can be classified into three types:

1. Renewal of power
2. Power Transfer
3. Domestic Uncertainty
   a) over foreign affairs
   b) over domestic affairs

If a domestic event of type 1 occurs, β_o and β_a are increased by $m_{\beta o}$ and $m_{\beta a}$ respectively.

If a domestic event of either type 2 or type 3a occurs, α_o, α_a, β_o and β_a are increased by $m_{\alpha o}$, $m_{\alpha a}$, $m_{\beta o}$, and $m_{\beta a}$ respectively.

If a domestic event of type 2 occurs, the probability of goal setters making the decision is increased using the rule $P_{N+1} = P_N + \alpha_b (1 - P_N)$.

If a domestic event of type 3a occurs, the probability of goal setters making the decision is increased in accordance with the rule $P_{N+1} = P_N + \alpha_b (1 - P_N)$.

If a domestic event of type 3b occurs, the probability of goal setters making the decision is decreased in accordance with the rule $P_{N+1} = P_N - \beta_b P_N$.

THE IMPACT OF THIRD PARTIES

All of the substantive discussion to this point has been in terms of two-nation interaction. This would be fine if the world were composed of two nations, but it is not. Therefore we need to look at the systemic impacts upon the actor and object nations. We have chosen to approach this problem by examining the impact of third parties upon the reciprocity between nations in the dyad.

We contend that third parties can have an impact on dyadic relations in three possible ways. The first is predicated upon the assumption that the actions of a nation's dyadic partner toward a third party can be perceived as relevant to the achievement of the nation's goals with reference to the third party. For example, if we define a dyad composed of the nations i and j (see figure 1) with i as the actor, and j initiates some behavior toward a third party h, i may modify its behavior toward j to influence j to either stop its behavior toward h, or to influence j to continue or increase its behvior toward h if that behavior is conducive to the achievement of i's goals with respect to h.

This is not a new position in the literature on foreign policy. Harary(1961) has explored the relations among three nations (a triad) from the perspective of balance theory. The fundamental rule of behavior for this appraoch, he argued, was that "a friend of my friend is my friend, a friend of my enemy is my enemy, an enemy of my enemy is my friend, and an enemy of my friend is my enemy." By applying this rule, nations modify their behavior so that a situation is brought about in which only one pair or all three pairs of dyads in a triad are friendly.

Illustrative examples of the impact of third parties abound. The behavior of President Nixon toward the Soviet Union and the People's Republic of China, it can be suggested, was influenced to a great deal by his desire to get them to cut off or cut back their aid to North Vietnam. In December of 1972, Sweden's actions toward the United States changed drastically due to American actions toward North Vietnam. Periodically, the United States Places its West European allies under tremendous pressure to increase their allocations for economic and technical assistance to the poorer nations of the world. And in the winter and spring of 1973, Israel launched a number of military raids against Lebanon in order to coerce that nation into placing restrictions on the activities of Palestinian guerrillas.

Two problems, though, exist in the previous writings on the impact of third parties. One is that the theoretical focus is too narrow. The example of U.S. actions toward Western Europe concerning foreign aid indicates a weakness in the Harary formulations since he does not provide a handle for dealing with the case of under-cooperation, as opposed to outright conflict.

The second difficulty is that they provide only bivariate hypotheses. They indicate the potential relevance of a new class of variables, third parties, but fail to indicate how they should be used in conjunction with the traditional dyadic focus. Without further theoretical development a researcher would be forced to look only at one approach or the other, not both at the same time. The problem is that it is possible for the needs of dyadic interactions and triadic interactions to contradict (for a formal proof of this position see

Phillips and Callahan, 1973:20-21). Thus we need a set of rules which will inform us when to expect the dictates of dyadic interactions to dominate the dictates of triadic interactions, and vice versa.

The search for such rules has so far led us to posit the following four potential rules. All seek to identify conditions under which the goals relating to a third party will seem to the actor nation to be more important than the goals relating to the object nation.

The first rule is based in the body of theory which is usually referred to as social field theory or social distance theory (Lewin, 1951; Wright, 1955; Rummel, 1965, 1971). The essence of this perspective is that social units can be represented as an agglomeration of attributes. These attributes can be employed to define a multidimensional field. Individual units can be located in this field, and distances between individual units can be measured. The smaller the distance the more alike are the units. The fundamental theorem of social field theory or social distance theory is that the distances(or dissimilarities and similarities) between social units have an impact on the behavior of the units toward each other. Quincy Wright's homely expression of this idea was to portray nations as maggots in a cheese:

> They vaguely perceive each other as they approach, often changing directions in response to primitive instincts and urges, to sophisticated patterns and policies, and to deliberate appraisals of purposes and powers (1955:546).

Whereas previous work in social field/social distance theory has been focused on the dyadic level, we believe that it would be useful to

apply it to the interactions in triads. The position we propose is that the smaller the social distance between the third party and the actor, the more significant the interactions involving the third party in determining the behavior of the actor. The rule would then be that actors will sacrifice dyadic reciprocity if the third party is closer in terms of social distance, to the actor.

The second rule is based on the supposed importance of a nation's ideology in determining its foreign policy behavior. The assumption is that there is a class of nations for whom various third parties have some specific ideological import. In some cases the set of nations can be fairly large. For example, the United States defines for itself the ideological position of protector of the "free world," the Soviet Union sees itself as the defender of the Socialist sphere, and the People's Republic of China sets itself up as the leader of the underdeveloped world. The assumption we adopt is that if the actor has some particular ideological interest in the affairs of the third party, then it will be responsive to the interactions involving that third party. The rule would thus be that a nation will sacrifice dyadic reciprocity if it has sufficient ideological interest in the third party.

The third rule derives loosely from balance of power theory. That theory suggests that nations will form alliances in such a manner that no single nation or group of nations will achieve preponderance in the international system. In the pursuit of the balance of power nations will attend to no other factors in a situation other than the need to balance power. A nation which wishes to balance power must direct hostility toward the dominant nation and support toward the

nations which are in danger of being controlled. This suggests the rule that nations will sacrifice dyadic reciprocity when it (dyadic reciprocity) would require failure to balance power in the international system.

The fourth rule is based on the supposition that nations will respond to interactions involving third parties only when the behaviors involved are at a high level of intensity. To alter Harary's formulation, an enemy of my friend is my enemy only if he is directing extreme conflict towards my friend. Otherwise, there is no clear and present danger presented by the conflict situation: the status quo could continue for some time without presenting a threat to the well-being of the friend. In such cases, actors may not modify dyadic reciprocity in order to alter the triadic configuration, choosing rather to hope that the situation would be cured on its own.

A second approach to the impact of third parties is closely tied to our communications perspective. This involves the potential impact of communication overload in a triad. If the actions of nation i to nation j and back again are heavy enough, the attention of the decision-makers in nation i or nation j would be so focused on that interaction that the actions of nation h to either nation would not be perceived accurately and responded to appropriately.

The third possible way for third parties to have an impact on reciprocity is applicable only to relatively hierarchical political systems where the capacity to apply punitive sanctions is heavily in favor of one of the nations in the system. In such a case, it may be possible that the underdog will modify its behavior so as to communicate to the topdog the similarity of their goals and policies. This

would be in order to avoid the application of punishment that might follow from the perception of the topdog that the underdog was pursuing goals which contradicted the goals of the topdog. Instances where such a process may be hypothesized as having happened are the policies of the nations of the Soviet bloc prior to the Sino-Soviet split (which may have been adjusted to appease the Soviet Union at the expense of reciprocating friendly overtures from Western nations) and the foreign policies of Latin American nations who did not wish to alienate the United States. It should be emphasized that these examples are only hypothetical. No assertion that they are true is made, nor is it claimed that others assert them.

Some aspects of the impact of third parties in dyadic behavior can be incorporated through axioms previously presented. Therefore only one additional rule needs to be advanced to complete the inclusion of the substantive argument above.

Rule 20. Once the actor i and object j are chosen, if the last act was:

a) From j to another nation h, the probability that i chooses the same act that j directed toward h is increased according to the rule $P_{N+1} = P_N + \alpha_t (1 - P_N)$ regardless of j's last act toward i.

b) From h to the actor i, the probability that i's behavior to j will be the same as the

act that h directed to i is diminished according to the rule $P_{N+1} = P_N - \beta_t P_N$. With the statement of this rule the substance of the theory has been completely presented.

SUMMARY

At this juncture all the elements of the theory have been presented and substantive justification has been given for their inclusion. The vehicle (mathematical learning theory) for integrating all these elements has also been presented. However, until all elements of the theory have been given an explicit integration into the theory, we shall have accomplished no more than to reiterate a series of hypotheses. We therefore turn to the job of integrating the parts.

As mentioned previously the theory is in the form of a Monte Carlo computer simulation. A sequence of decisions is made by the computer on the basis of the instructions given it. These decisions determine the values of the key variables of each event: the actor, the object, the action type, and the level of the decision-makers involved in the actor nation.

The operation of the simulation is on an event-by-event basis. One event is produced by the machine and then a series of modifications in parameters and memory are made before the next event is generated. Thus, one can think of the simulation as having a series of cycles, with each cycle dependent in part upon the outcomes of the previous cycles.

Each cycle begins with the choice of an actor. This step was defined substantively in Rule 4 (page 14). Unlike most aspects of the

simulation, the choice of actor in each cycle is not dependent upon results of previous cycles. Rather, the probabilities of each nation being the actor have been calculated from empirical data, and are fixed.

Next, the identity of the object of the action is determined. Like the choice of actor, this step is not especially complicated. Essentially the object is determined from the matrix of probabilities which results from Rule 5, page 14. Initially, the probabilities in this matrix are those derived from analysis of empirical data. In all succeeding cycles these probabilities are modified on the basis of whether the exchanges between each nation and various other nations are rewarding or punishing. The process through which this occurs is part of the learning routine and is described in Rules 10 and 11, pages 15 and 16.

The actor's decision-makers must next choose the type of action to be sent to the object. Before they do this, they check how effective their prior behavior has been in helping them achieve their goals. The check is made by examining the last act they sent to the object and the last act received from the object. A comparison is made between these actions to determine if the exchange was rewarding or punishing. For example, suppose that the goal of the actor is cooperative relationships. It then looks at its action to see if it has elicited a cooperative response. If so, the exchange was rewarding and the decision-makers will want to increase the probability of sending the same action this time. In other words, learning has taken place. In the simulation, this occurs through use of the algorithm in Rule 13 (page 16). If the exchange was

unrewarding, then the decision-makers would want to decrease the probability of initiating the same kind of event. Therefore, the learning algorithm set out in Rule 14 (pages 16 and 17) is employed.

Before the probabilities in the action-type vector are modified through learning, though, some other aspects of the situation may increase or decrease the sensitivity of the decision-makers to learning. In the simulation, this is accomplished through changes in some of the parameters of the learning algorithm. One such aspect is the level of relative uncertainty.

In the simulation, the actor looks back into his memory and examines the last 8 events received from the object nation. The H_{rel} statistic is calculated on the basis of these 8 events. The impact of H_{rel} on the learning algorithm is described in Rule 15 (page 23).

Two other areas, bureaucratic politics and domestic events, both have their impact on learning by bringing into the decision-making process the top political decision-makers in the nation, which accelerates learning according to the rule in Rule 17 (page 27).

In the simulation, two variables help to determine if the top political decision-makers are involved. One is a vector of probabilities (estimated from empirical data) that top decision-makers are involved. This vector is itself modified by the level of H_{rel}, according to the rule in Rule 18, page 27).

After the values of the parameters in the learning algorithms have been determined in this way, the learning calculations are carried out and the probabilities in the action-type matrix are modified according to the rules in Rules 13 and 14 (pages 16 and 17).

Before the action-type is chosen, however, one other variable has an effect; that variable is the impact of third parties. Third party considerations act directly on the matrix of action-type probabilities according to the rule articulated in Rule 20 (pages 36 and 37).

The crucial variables in the event will have thus been decided. One cycle in the simulation is nearly completed. The only thing remaining to be done is to change the probabilities in the object's object-choice vector. This is done by the object evaluating the sequence of events defined by this most recent event and the last previous one in which the present actor and object were reversed. The evaluation process has been described above (p. 38), and is loosely analogous to that performed with respect to action type. On the basis of the evaluation, the vector of objects is modified according to Rules 10 and 11 (pages 15-15). Once this is done, the cycle is completed and control passes to the next cycle.

CONCLUSION

A well-known maxim (of Destouches)--often quoted but rarely heeded--says that every paper beginning with axioms should be preceeded by another paper justifying the choice of those axioms. In the present case we have tried to adhere to Destouches' admonition; this paper has attempted to provide the reader with a justification for each Rule and to whet the appetite for what is to follow. In a second article we will lay out the formal, axiomatic theory of which the simulation presented here is a model.

FOOTNOTES

1. This paper was prepared in connection with research supported by the Advanced Research Projects Agency, ARPA Order No. 2345-3D20, Contract No. DAHC15-73-C-0197, RF 3527-A1. This document has been approved for public release and sale; its distribution is unlimited and reproduction in whole or in parts is permitted for any purpose of the United States Government.

The authors wish to thank those students at Ohio State University who have been working along on the development of this computer simulation. Special thanks go to John Thompson, Yong-ok Park, and Dick Stoddard.

2. For the serious implications of attempting analysis before structure has been posited in time series analysis see the excellent critique by Hibbs (1972).

3. The point is continually emphasized in Popper (1959), "The initial stage, the act of conceiving or inventing a theory, seems to me neither to call for logical analysis nor to be susceptible of it. The question, how it happens that a new idea occurs to a man--whether it is a musical theme, or a dramatic conflict, or scientific theory--may be of great interest to empirical psychology; but it is irrelevant to the logical analysis of scientific knowledge. This latter is concerned not with *questions of fact* (Kants *quid facti?*), but only with questions of *justification or validity* (Kants *quid juris?*), its questions are of the following kind. Can a statement be justified? And if so, how? Is it testable? Is it logically dependent on certain other statements? Or does it perhaps

contradict them? In order that a statement may be logically examined in this way, it must have already been presented to us. Someone must have formulated it, and submitted it to logical examination." (Popper, 1959:31)

4. Such a scheme can be likened to the criteria that a map maker brings to the drawing of a particular map. The criteria for deciding whether or not to include roads, or altitude plus or minus sea level, depends on the cartographer's perception of what the map is to be used for. Toulmin likens the drawing of a map to the laying out of a theory (1953). In this article we attempt to lay out our goals or criteria which we will use in specifying a theory of foreign policy interactions.

5. Research in psychology tends to support the notion of reciprocity. Taylor (1965) and Tognoli (1967) provide evidence suggesting that increases in the intimacy of a subject are due to the increasing intimacy of his companion's remarks. Changes in the rate of smiling also tend to be reciprocated in the same time (Kendon, 1967). Explanation for the norm of reciprocity may be found in Gouldner (1960) and Pruitt (1965, 1968). Homans (1961) has attempted to explain reciprocity in terms of stimulus-response learning theory.

6. Goldman (1972:70) describes similar communication rules for domestic politics.

7. Parallel themes run through a recent article by Turpin, who states, for example, " . . . that when situations arise in the course of conducting 'foreign relations' which impinge on the President's sphere of 'power,' the State Department is shunted away from the controls. As the then Dominican Desk Officer is reported to have said of the 1964 crisis, "On Friday I was Dominican Desk officer; by Friday night Rusk

was; and by Sunday noon Lyndon Johnson was." (1972:57).

8. Personal and domestic political interests, for instance, are especially important as well; so also are shared conceptions of the national interest.

9. The authors recognize that relatively large bodies of literature exist concerning both organization theory and the importance of bureaucratic considerations in determining foreign policy. It is not our intent to minimize the importance of any of these works. However, within the scope of this article any really thorough review of this literature seems impossible, as does any detailed development of the bureaucratic politics paradigm. Fortunately, as George (1972:Fn. 29) has pointed out with respect to the area of bureaucratic considerations, "Graham T. Allison has brilliantly codified and explicated much of the previous literature on bureaucratic politics by writers such as Linblom, Neustadt, Schilling, Hammond, Huntington, [and] Hilsman." Thus one may, by examining Allison's book, get a good overview of the earlier work.

10. A dismissed regime could, of course, be replaced by one pledged to continue its predecessor's policies. Since the regime is different, we would still classify such an event as a power transfer. In addition, it seems likely that the new regime would involve itself actively in the foreign policy process in order to assure itself that continuity was, in fact, being maintained. Along with this involvement would probably go (at least initially) an increased sensitivity to whether the outputs chosen were successful or not, even though the criteria for success may have been carried over from the previous regime.

11. The term "popular support", as used here, should be taken to mean mass or parliamentary support in western style democracies, and support of the influential elites in other forms of government.

12. Economic problems serve as a good example here. Consider the current problems of senior officials and government agencies in the United States who, because of popular concern, must be more attentive to the balance of payments and to trade policy on some occasions and to domestic unemployment and to inflation on others. Regardless of whether or not the problems are related, the agency is likely to shift the bulk of its command and control resources from one area to another in the face of significant domestic concern (especially during election years).

BIBLIOGRAPHY

ALLISON, G.T. (1971) *Essence of Decision: Explaining the Cuban Missile Crisis.* Boston: Little, Brown.

--- AND M.H. HALPERIN (1972) "Bureaucratic Politics: A Paradigm and Some Policy Implications." *World Politics.* Supplement to Vol. XXIV.

ASHBY, W.R. (1952) *Introduction to Cybernetics.* New York: Barnes and Noble.

AZAR, E.A. (1970) "Profiling and Predicting Patterns of Inter-Nation Interactions: A Signal Accounting Model." Paper presented at the APSA Annual Meeting in Los Angeles, Ca. (September).

BARTOS, O. (1966) "Concession-Making in Experimental Negotiations." In J. Berger, M. Zelditch, Jr., and B. Anderson *Sociological Theories in Progress.* New York: Houghton Mifflin.

BRUNER, J.S. (1960) *The Process of Education.* Harvard University Press.

BRUNNER, R.P. (1970) "Data Analysis, Proven Analysis and System Change." Paper prepared for the 66th Annual Meeting of APSA.

BURTON, J. (1969) *Systems, States Diplomacy and Rules.* Cambridge University Press.

--- (1968) *Conflict and Communication.* New York: Free Press.

BUSH, R. AND F. MOSTELLER (1955) *Stochastic Models for Learning.* New York: John Wiley and Sons.

--- (1951) "A Mathematical Model for Simple Learning." *Psychological Review.*

CAIN, G. AND H. WATTS (1970) "Problems in Making Policy Inference from the Coleman Report." *American Sociological Review,* (April).

CHERRY, C. (1957) *On Human Communications*. Cambridge: MIT Press.

DEUTSCH, K. (1968) *The Analysis of International Relations*. Englewood Cliffs: Prentice Hall.

--- (1953) *Nationalism and Social Communications: An Inquiry into the Foundations of Nationality*. Massachusetts: MIT Press.

FORRESTER, J. (1971) "Counter Intuitive Behavior of Social Systems." *Technology Review*. (January).

GEORGE, A.L. (1972) "The Case for Multiple Advocacy in Making Foreign Policy." *The American Political Science Review*. Vol. LXVI (September).

GOLDMAN, R. (1972) *Contemporary Perspectives on Politics*. Princeton: D. Van Nostrand Co.

GOULDNER, A.W. (1960) "The Norm of Reciprocity: A Preliminary Statement," *American Sociological Review*. Vol. XXV.

HALPERIN, M.H. (1972a) *Bureaucratic Politics and Foreign Policy*. Washington, D.C.: Brookings Institution [Draft manuscript].

--- (1972b) "The Decision to Deploy the ABM: Bureaucratic and Domestic Politics in the Johnson Administration." *World Politics*, Vol. XXXV.

--- (1971) "Why Bureaucrats Play Games." *Foreign Policy*. No. 2.

--- AND A. KANTER [Eds.] (1973) *Readings in American Foreign Policy: A Bureaucratic Perspective*. Boston: Little, Brown.

HARARY, F. (1961) "A Structural Analysis of the Situation in the Middle East in 1956." *Journal of Conflict Resolution*.

HIBBS, D.A. (1972) "Problems of Statistical Estimation and Causal Inference in Dynamic, Time-Series Regression Models." Paper prepared for delivery at the 1972 APSA Meetings.

HOLSTI, O. (1965) "Perceptions of Time, Perceptions of Alternatives and Patterns of Communication as Factors in Crisis Decision-Making." *American Political Science Review*. Vol. LIX.

---, R.A. Brody and R.C. North (1968) "Perception and Action in the 1914 Crisis." In J.D. Singer (Ed.) *Quantitative International Politics: Insights and Evidence*. New York: The Free Press.

HOMANS, G.C. (1961) *Social Behavior: Its Elementary Forms*. New York: Harcourt, Brace and Co.

JERVIS, R. (1970) *The Logic of Images in International Relations*. Princeton: Princeton University Press.

KENDON, A. (1967) "Some Functions of Gaze-Direction in Social Interaction." *Acta Psychologica*. Vol. XVI.

LENG, R. (1972) "Behavioral Indicators of War Proneness in Bilateral Conflicts," A paper prepared for the 1972 Annual Meetings of APSA, Washington Hilton Hotel, Washington, D.C. (Sept. 5-9).

LEWIN, K. (1964) *Field Theory in Social Science* D. Cartwright (Ed.) New York: Harper Torchbooks.

MCCLELLAND, C.A. (1973) "The Beginning, Duration, and Abatement of International Crises: Comparisons in Two Conflict Arenas." In C.F. Hermann (Ed.) *International Crises*. New York: Free Press.

--- (1968) "Access to Berlin: The Quantity and Variety of Events, 1948-1963." In J.D. Singer (Ed.) *Quantitative International Politics: Insights and Evidence*. New York: Free Press.

--- (1967) "International Communications." In *The International Encyclopedia of the Social Sciences.* New York: MacMillen.

--- (1965) "Systems Theory and Human Conflict." In E.B. McNeill (Ed.) *The Nature of Human Conflict.* Englewood Cliffs: Prentice Hall.

--- AND G.D. HOGGARD (1969) "Conflict Patterns in the Interactions Among Nations" in J.D. Rosenau (Ed.) *International Politics and Foreign Policy: A Reader in Research and Theory.* New York: Free Press.

NEUSTADT, R. (1970) *Alliance Politics.* New York: Columbia University Press.

PHILLIPS, W.R. (1973a) "Theoretical Approaches to the Event Data Movement." Presented at the Annual Meeting of the ISA in New York (March). To appear in C. Kegley, G. Raymond, R.M. Rood and R. Skinner's (Eds.) *International Events and the Comparative Analysis of Foreign Policy.*

--- (1973b) "The Conflict Environment of Nations: A Study of Conflict Inputs to Nations in 1963." In J. Wilkenfeld (Ed.) *Conflict Behavior and Linkage Politics.* New York: David McKay.

--- (1973c) "International Communications." Forthcoming in M. Haas (Ed.) *Behavioral International Relations* (Chandler Press).

--- (1971) "The Dynamics of Behavioral Action and Reaction in International Conflict." Papers of the Peace Research Society.

--- AND P.T. CALLAHAN (1973) "Dynamic Foreign Policy Interactions: Some Implications for a Non-Dyadic World." Ohio State University mimeo.

--- AND R.C. CRAIN (1972) "Dynamic Foreign Policy Interactions," University's Mershon Center mimeo (August).

POPPER, K. (1959) *The Logic of Scientific Discovery.* New York: Harper Torchbooks.

PRUITT, D. (1969) "Stability and Sudden Change in Interpersonal and International Affairs." In J.N. Rosenau (Ed.) *International Politics and Foreign Policy: A Reader in Research and Theory.* New York: Free Press.

--- (1968) "Reciprocity and Credit Building in a Laboratory." *Journal of Personality and Social Psychology.* Vol. VIII.

--- (1965) "Definition of the Situation as a Determinant of International Action," in H.C. Kelman (Ed.) *International Behavior: A Social-Psychological Analysis.* New York: Holt, Rinehart and Winston.

RAINIO, K. (1966) "A Study of Sociometric Group Structure: An Application of a Stochastic Theory of Social Interaction." In Berger, Zelditch and Swanson, *Sociological Theories in Progress.* New York: Houghton Mifflin.

RUMMEL, R.H. (1971) "A Status Field Theory of International Relations." DON Research Report # 50.

--- (1965) " A Field Theory of Social Action with Application to Conflict Within Nations." *General Systems: Yearbook of the Society for General Systems Research,* Vol. X.

--- (1963) "Dimensions of Conflict Behavior Within and Between Nations." *General Systems: Yearbook of the Society for General Systems Research.* Vol. VIII.

SCHELLING, T.C. (1960) *The Strategy of Conflict.* New York: Oxford University Press.

SHANNON, C.E. AND W. WEAVER (1949) *The Mathematical Theory of Communication*. Urbana: University of Illinois Press.

SMOKER, P. (1969) "A Time Series Analysis of Sino-Indian Relations." *Journal of Conflict Resolution*. Vol. XIII (June).

TANTER, R. (1972) "Internal System and Foreign Policy Approaches: Implications for Conflict Modeling and Management." *World Politics*. Vol. XXIV.

TAYLOR, D.A. (1965) "Some Aspects of the Development of Interpersonal Relationships: Social Penetration Processes." University of Delaware, unpublished doctoral dissertation.

TOGNOLI, J.J. (1967) "Reciprocal Behavior in Interpersonal Information Exchange." University of Delaware, unpublished doctoral dissertation.

TOULMIN, S. (1953) *The Philosophy of Science*. New York: Harper & Row.

TURPIN, W.N. (1972) "Foreign Relations, Yes; Foreign Policy, No." *Foreign Policy*. Vol. VIII.

WIENER, M. (1950) *The Human Use of Human Beings*. Boston: Houghton Mifflin.

WRIGHT, Q. (1955) *The Study of International Relations*. New York: Appleton-Century-Crofts.

ZINNES, D. (1968) "The Expression and Perception of Hostility in Prewar Crisis: 1914," in J.D. Singer (Ed.) *Quantitative International Politics: Insights and Evidence*. New York: Free Press.

Figure 1 : A Triad

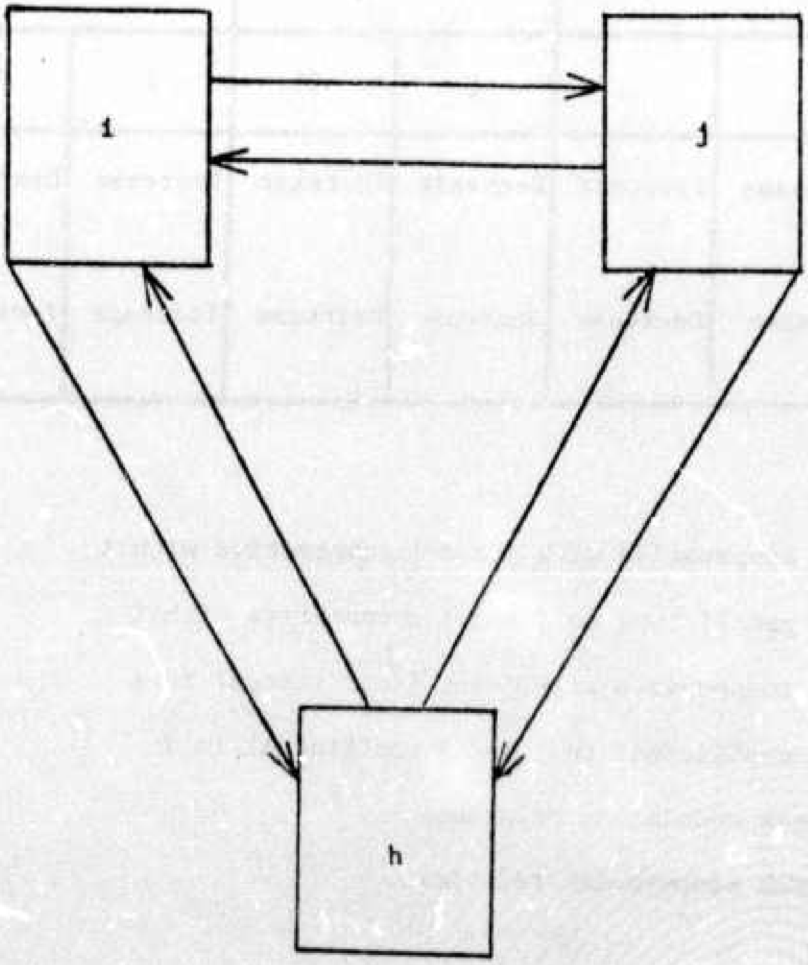


Table 1

Impact of Goals, Strategies and Dyadic Patterns on Probability of i Choosing j as Target Next Time

Dyadic Pattern	$i\ j$[1]		$\bar{i}\ j$[2]		$i\ \bar{j}$[3]		$\bar{i}\ \bar{j}$[4]	
Goal	I[5]	II[6]	I	II	I	II	I	II
Strategy: Reinforcement	Increase	Increase	Decrease	Increase	Decrease	Decrease	Increase	Decrease
Strategy: Conversion	Decrease	Decrease	Increase	Decrease	Increase	Increase	Decrease	Increase

1 i cooperative with j and j cooperative with i

2 i conflictual to j and j cooperative with i

3 i cooperative with j and j conflictual to i

4 i conflictual to j and j conflictual to i

5 seek consistent relations

6 seek cooperative relations

Table 2

	A	1
	B	1
	C	1
BEHAVIOR TYPE	D	1
	E	1
	F	1
	G	1
	H	1
TOTAL		8
HREL		1.0

Table 3

	A	0
	B	0
	C	0
BEHAVIOR TYPE	D	4
	E	4
	F	0
	G	0
	H	0
TOTAL		8
HREL		0.33

Iran's Goals

Iran is an interesting case for the study of national goals. It is a monarchy which professes to have a revolutionary program. It has managed a phenomenal growth rate and has also emerged as one of the leading military powers in the Middle East and Western Asia. As an oil producer and an intended policeman of the Persian Gulf region, Iran's goals warrant the attention of American policy-makers.

In terms of immediate problems the most important goals to the Iranian leadership appear to be foreign policy goals. Iran finds itself in a precarious position. It has traditionally been pro-Western in its foreign policy, although only hostile to the U.S.S.R. when that country was less than friendly. It is now bordered half way around its perimeter by nations which are either openly hostile (Iraq, because of antimonarchial ideology, Afghanistan for similar reasons) or suspect (the USSR because of historical aggressive intentions and because of its alliance with Iraq). Across the Persian Gulf are Arab states, some conservative (Saudi Arabia, Kuwait) some revolutionary (PDRY). None are overly friendly, due to the non-Arabian nature of Iran, its failure to support the Arabs against Israel, competition in the oil market and Iran's independent approach to dealing with the petroleum companies. Iran's only sure ally is Pakistan, and it has shown itself as frighteningly weak militarily. There is no Western policeman in the gulf region since the British pull out and the Soviet navy has a

significant presence in the Indian Ocean nearby. These conditions prompted the Economist to refer to the Iranian situation as "The Encircled Shah" and attribute that perception to him.[128]

The potential impact of foreign affairs on Iran's future is thus very great. Political instability in the Gulf would not only threaten the closing of the Gulf, shutting off oil exports and thus crippling the economy, but could also threaten the continued existence of the regime. Therefore, the Shah has instituted a program of military development that involves the purchase of the most sophisticated equipment on the market. The military program has taken a significant bite out of the budget (26% of the general budget, about 10% of the total budget). Aside from communication and telecommunications the military expenditures has been the fastest growing segment of the general budget since 1968 and has been the fastest growing in absolute increase.

In addition to the military development, the Shah has engaged in wide-ranging personal bilateral diplomacy seeking new friends and the moderation of the Soviet Union.

The second most important goal of the regime has been economic development. Their strategy in pursuing industrialization has been to invest public funds in heavy industries and in building up the infrastructure and to allow and even encourage the participation of private enterprise in the economy. According to the Information and Press Department

in the amount budgeted for the General Investment Fund and Petroleum Participation, from an insignificant amount in previous years to 11.2% in the most recent budget. What this probably indicates is a rise in the importance of national control of the petroleum sector, although the functional breakdown of that allocation is not available.

Next in the list of priorities of the government is another infrastructural area. That is the improvement of the cities. The municipal affairs agency has received between 4.9 and 8.5% of the budget over the last four years. These funds are employed mostly to establish sewer systems, pave streets, provide streetlights and sidewalks and build markets and slaughter houses. Another aspect of the improvement of municipalities is provision of water. This is also well budgeted, taking up 37% of the allocation of the ministry of agriculture and water in a year when that ministry received 5.4% of the national budget.

Two goals which do not constitute major goals of the government are the rapid development of the agricultural sector and rapid industrialization. The allocations in the budget for agricultural development do not constitute a large portion of the budget. The stated strategy of the regime in agriculture is to increase the amount of arable land through irrigation, then to distribute fallow land to peasants and bedouins. Three things are hoped for from this strategy:

first, to increase the amount of available food; second, to reduce imports;[62] third, to integrate the bedouins into the society better.[63] But despite the fact that slightly over 1/3 of all Saudi imports are foodstuffs,[64] very little has been done for agriculture. Only 2% of imports are tractors or agricultural machinery.[65] Only one dam has been built and only three other irrigation projects have been begun.[66]

Saudi industrial strategy has been to build industrial estates with the complete infrastructure for plant development. So far three have been built.[67]

In these, private investment will occur. Government avoids direct investment in industry. Of 240 industrial establishments at most 47 have government financing. Of the total capital in these projects only 9% has been put up by the government, and most of that has been for plants producing construction and building material.[68] The ministry of commerce and industry has less than 1% of the budget allotted to it.

Because of its lack of concern for quick development the Saudi government is not faced with the major bottlenecks as much as is the case with more revolutionary regimes. Manpower for industry is a problem for private industry. Its only pinch is in teaching, and to solve that it both trains teachers and it hires an extensive number of Egyptian teachers.[69]

Because of its tremendous oil revenues Saudi Arabia is under no special restraints due to financial bottlenecks. In-

deed, Faisal let it be known that he would not be upset to reduce oil sales to the United States since present revenues are more than the economy can presently absorb in development expenditures.

Finally, in line with the conservative nature of the regime, it spends a great deal on religious matters each year, including allocations for mosque maintenance, religious affairs, public morality in Najd and Hijaz, and for provision of water and road facilities for pilgrims to the holy cities.

Table 2: Percentage distribution of Saudi Arabian budgetary allocations over a four year period.***

	1390/1391	1391/1392	1392/1393	1393/1394
Private Treasury	2.6	1.6	1.3	.8
Royal Cabinets	.3	.2	.2	.2
Presidency of the Council of Ministers	.2	.2	.2	.1
National Guard	4.3	3.2	3.1	2.8
Intelligence	.3	.4	.2	.3
Public Works Department	.2	.1	.3	.4
Ministry of Information	1.2	1.1	1.3	1.1
Ministry of Foreign Affairs	.9	.7	.8	.7
Ministry of Defense and Aviation	28.5	21.8	26.9	23.7
Ministry of Interior	4.9	6.0	7.4	5.7
Municipal Affairs	12.6	12.8	6.7	8.5
Ministry of Labour and Social Affairs	1.6	1.4	1.3	1.0
Ministry of Health	2.7	2.6	3.2	2.6
Ministry of Education	6.6	6.7	10.7	8.6
Ministry of Communication: Roads and Ports	7.5	17.6	8.1	7.9
Ministry of Communication: Posts and Telegraphs	2.2	3.5	2.7	2.0
Ministry of Finance and National Economy	3.8	4.9	5.9	5.9
Ministry of Petroleum and Mineral Resources	.9	1.0	.9	.8
Ministry of Commerce and Industry	.4	.5	.5	.4

Table 2 (cont)

	1390/ 1391	1391/ 1392	1392/ 1393	1393/ 1394
Ministry of Agriculture and Water Resources	4.8	5.4	5.4	4.5
Ministry of Justice	.6	.6	.5	.4
Public Allocations and Subsidies	.8	.5	.4	.2
Pension and Social Insurance	1.2	1.5	1.3	1.3
Subsidy for Public Corporations	2.7	2.5	2.5	1.9
Emergency Expenditure	.9	.6	.5	.9
Islamic Affairs	.3	.2	.4	.2
Aid to Arab Countries	6.1	6.1	5.0	2.9
General Reserves	---	2.3	2.3	2.0
General Investment Fund and Petroleum Participation	---	3.2	1.9	11.2
Total Expenditure in Thousands of Saudi Riyals	6380	10782	13200	22810

* Sources: "Saudi Arabian Budget for 1973/1974" and Jidda A-90

** Data are aggregated by Ministry where more detailed data were available. Expenditures which never accounted for more than .1 of the budget were ignored.

*** 1970/1971

Iraq's Goals

An examination of Iraq's goals over the past couple of years presents an interesting challenge to the American analyst. On the one hand, the problem area is data-poor. The United States and Iraq do not have diplomatic relations so there are no analyses by American governmental experts to draw on as there are for other nations. Nor are there adequate budget data available. Second, within the past couple of years Iraq was engaged in a monumental clash with the petroleum companies operating within its borders, and that clash had the consequences of distorting the actions taken by the government. On the other hand the choices made in a crisis may be instructive.

The foreign policy goals of the Iraqi regime seem to be the ost important goals to them. Of the foreign policy goals, the most significant seems to be the return to the Arab states of the lands taken by the Israeli's in previous wars. Thus Al-Bakr has declared: "Citizens, the revolution has defined its position regarding international relations on principled bases, the first of which is the attitude toward the legitimate Arab causes of liberation, unity and progress--foremost of which is the Palestinian cause."[70] Other foreign policy goals of some importance to the regime are the unification of the Arab states and the elimination of monarchies in the Middle East.

Iraqi actions provide some support for this assertion

of the importance of goals. Iraq sent troops to assist in the conflict with Israel during the war of 1973. It has allocated a giant (25%) chunk of its budget for military purposes. This money has been employed to put the heat on two traditional regimes on Iraq's borders: Iran and Kuwait. The conflict with Iran has apparently involved some serious border clashes. And in addition to its defense activities, the recipients being Abu Dhabi, Somalia, and the Arab Fund for Economic and Social Development.[71]

The second most important goal of the Iraqi regime has been the development of petroleum sector under Iraqi control. The regime has made extensive investments in upstream capabilities under the control of the Iraqi National Oil Company (INOC). For example, it has contracted in the 1971-72 period to spend nearly $169 million to develop a tanker fleet, not counting the cost of leasing Russian tankers, which is part of their plan.[72] They have also begun work on two refineries[73] and on a petrochemical complex.[74] And they have paid a great deal of attention to the development of the North Rumaila field, INOC's primary deposit.

Particularly indicative of the signal importance of the goal of exerting national control over the petroleum industry are the actions of the regime in the crisis following the nationalization of the IPC. Whereas all other programs of the government were slashed in an attempt to save foreign exchange reserves, the budget of the Iraqi National Oil Company was

untouched.

The third most important goal of the regime has been exerting control of the regime over foreign petroleum operations. Actions taken in this area include pressuring the French company ELF-ERAP to give up 65% of its concession area, demanding 20% participation and seats on the board of directors of the foreign oil companies operating in Iraq.[75]

A goal of perhaps equal or even greater importance to the regime is agricultural development. Agriculture was the third largest item in the budget, $213 million, which was 11.8% of total expenditures. It is not at all clear how this money is spent and thus what Iraqi agricultural strategy is. There is some action in the irrigation area and there have been efforts to create a fishing industry, including creation of a fleet and the building of a port at Umm Qasr. But both these were financed by foreign aid, as far as the examples in public sources indicate.[76] Another aspect of agricultural development is the selective treatment of the Kurdish areas of Iraq. In the period examined the civil war between Iraq and the Kurds had just been ended. In January of 1971 the government allocated money for such agricultural projects in the north as poultry breeding, beekeeping, fishing, fruit refrigeration and tobacco cultivation.[77] Whether this was part of the agricultural budget is not known.

Industrialization does not appear to be an important goal to the Iraqi leadership. My data indicates no major heavy in-

dustrial projects contracted for the period. The regime did allocate $182 million to industrialization, that being the fourth largest allocation in the budget at just over 10% of total allocations. In addition to it being not a particularly large amount spent, that allocation may include money for projects associated with the petroleum industry. Among the smaller industrial projects begun are some that are closely oriented toward the agricultural sector (tobacco factory, sugar beet refinery). Some appear to be primarily intended to help pacify the Kurds.[78]

The Iraqi regime appears to have as a goal the development of the mining sector. It has negotiated deals to sell sulphur, exploit phosphate deposits and to locate deposits of zinc, iron, lead, and radioactive elements.[79] The main goals of this interest in minerals are probably to diverify Iraqi exports so as to lessen its dependence on oil, and to increase exports in order to increase government foreign-exchange revenue.

As the budgetary data indicates, Iraq spends a considerable portion of its money on education, 12.6%. Part of the regime's educational strategy is the elemination of illiteracy. The anti-illiteracy campaign includes the establishment of 650 literacy centers at a cost of $70.25 million and the requirement that no illiterate may hold official or semi-offical employment unless he or she attends an anti-illiteracy center.[80]

In the manpower realm the Iraqi regime has apparently

adopted long-range strategies for meeting its needs. Partly it is able to do this because it does not have as a goal the quick transformation to an industrial nation. Partly it is due to Soviet cooperation in the development of Iraq's greatest oil deposit. The long-range strategy is indicated by the fact that many agreements made by the government with other countries concern Iraqi's going to those countries for training.[81]

Development of the infrastructure was not a very important goal for the Iraqi leadership. Expenditures constituted only 4.3% of the total. The major projects in this area were a canal from Tharthar to the Euphrates River and railroad expansion through purchase of diesel engines and cars.

Financial approaches of the regime were terribly distorted in this time period due to the IPC nationalization battle. The main strategy of the regime appears to be to increase its oil revenues. Indeed, it was pursuit of this goal that touched off the IPC conflict, for the regime had been attempting to get the company to increase its production when it became apparent to them that the company had been bargaining in bad faith.[83] In addition to pressuring the private oil firms to increase production, the regime also sought new markets for oil, negotiating sales with Brazil and Bulgaria.[85] Finally, in order to increase oil revenues the regime sought to increase the tax rate on petroleum.[86]

Another aspect of Iraqi finance during the period that may have had long-term import was the extensive use of

foreign aid.[87] Basically this was a reflection of shifting foreign policy alignments towards the Communist bloc and foreign aid would have been a revenue source in any case. But the IPC battle undoubtedly accelerated the process. As a result, Iraq was heavily dependent on foreign aid in this period. A similar sort of process probably explains the Iraqi dependence on long-term foreign loans in the period, although taking out loans is probably an integral part of Iraqi financial strategy.

Minor aspects of Iraqi strategy include the promotion of tourism (a delegation was sent around the Persian Gulf states in 1971 for this purpose),[88] investment in other nations (joint control of a refinery in India)[87] and promotion of foreign investment by friendly nations in Iraq (Yugoslav participation in joint electrical and petrochemical projects, request for Arab investment).[90]

Table 3: Percentage breakdown of Iraqi budgetary expenditures 1968-1972

	1968	1969	1970	1971	1972
Defense	38%	43%	35%	29%	25%
Agriculture	n.a.	n.a.	n.a.	n.a.	n.a.
Education	17	15	14	12	13
Health	4	3	3	3	3
Other	22	21	21	20	18
Agriculture Capital	4	5	6	11	12
Industry Capital	6	5	6	9	10
Transportation and Communication Capital	3	3	3	5	5
Other Capital	6	5	10	11	14
Total Expenditure in Millions of Dinars	306	371	435	563	589

The Decision Module
Working Paper

Paul Anderson
Project for Theoretical Politics
Ohio State University

Project Research Paper No. 13

The research described in this paper was supported by the Advanced Research Projects Agency Contract No. DAHC 15 73 C 0197.

The decision module for the simulation will be disigned to provide country specific input values of variables to each of the three sector modules, oil, agriculture, and human resources. For the purpose of the decision module, nations will be conceptualized as goal seeking systems. Thus the mix of input variables and their values represent a choice of inputs that the decision-makers perceive to be relevant to controlling their perceived environment with respect to a desired environmental state. Using this notion of the nation, any analytic representation of the decision process must deal with two classes of problems: 1) What are the goals of the decision-makers and how do they change over time; and 2) Given the goals of the decision-makers, how are they transformed into values of manipulable variables?

The class of issues dealing with goal specification and goal change has received very little attention in the literature on the analysis of choice situations. It has generally been the case that the goals of the decision-makers have been specified as initial assumptions and are taken to be static over time, i.e., utility maximization given pre-assigned utilities to various outcomes. While in some situations that assumption is useful, in others it is not. In the case of the five oil producing nations, the goals are not totally static. While for the most part the basic goals or values of the nation do not change (i,e, survival) more specific goals or operational goals are not strictly determined from

the unchanging basic values or norms. Influences both within the nation and outside the nation may increase or decrease the importance of certain operational goals without changing the basic goal structure. One possible approach for dealing with changing short-term goals discussed below, is taken from Bossel and Hughes' "Simulation for Value Controlled Decision Making: Approach and Prototype" (1973), done in context of the Mesarovic - Pestel World Model Project.

The issues dealing with the choice of manipulable variables and their values given the goals has received considerably more attention. The main problems to be solved in this respect concern the development of a suitable representation for 1) the choices available to the decision-makers; 2) the subset of those possible choices perceived as relevant in a given situation; and 3) the means by which the alternatives and the goals are translated into actual choices. The representation of these three elements that is currently being considered is a spatial model of the possible choices with a Markov process interpretation of the actual choice from the alternatives. This representation is drawn largely from the works of Nelson and Winter (1972, 1973) and Nelson, Winter, and Schuette (1973) on evolutionary economic growth models.

The discussion of the two components of the decision module that follows should be considered as provisional solutions to the problems outlined above.

In dealing with the problems of changing goals in a decision

situation, Bossel and Hughes have conceptualized goals as being at the base of a hierarchically structured value network. At the top of the structure are superior values (i.e., survival). These superior values are relatively unchanging and support the remainder of the structure. Between the superior values and the operational goals are, in Bossel and Hughes' terms, "inferior values". It is the inferior values that link the specific goals to the general values, (See Figure 1, from Bossel and Hughes (1973)). Imposed on this norm structure are weights specifying the importance of the values and goals to the decision-makers. While the structure can be determined without reference to the norm weights, weights are necessary for decision making whenever more than one operational goal must be considered at the same time. In essence, the weights on the operational goals rank the goals in terms of importance. The weights of the values represent the importance of the content (i.e., resource usage) of the value to the system. To introduce a dynamic quality to the value structure, Bossel and Hughes use the concept of monitor variables. Monitor variables represent the perceptions of the environment by the decision-makers. Perceived changes in the monitor variables are responsible for changes in the weights and content of the operational goals.

For example, consider resource usage in a value structure. In Figure 1, resource usage would have a high weight because of its importance to the system, even if a variable monitoring

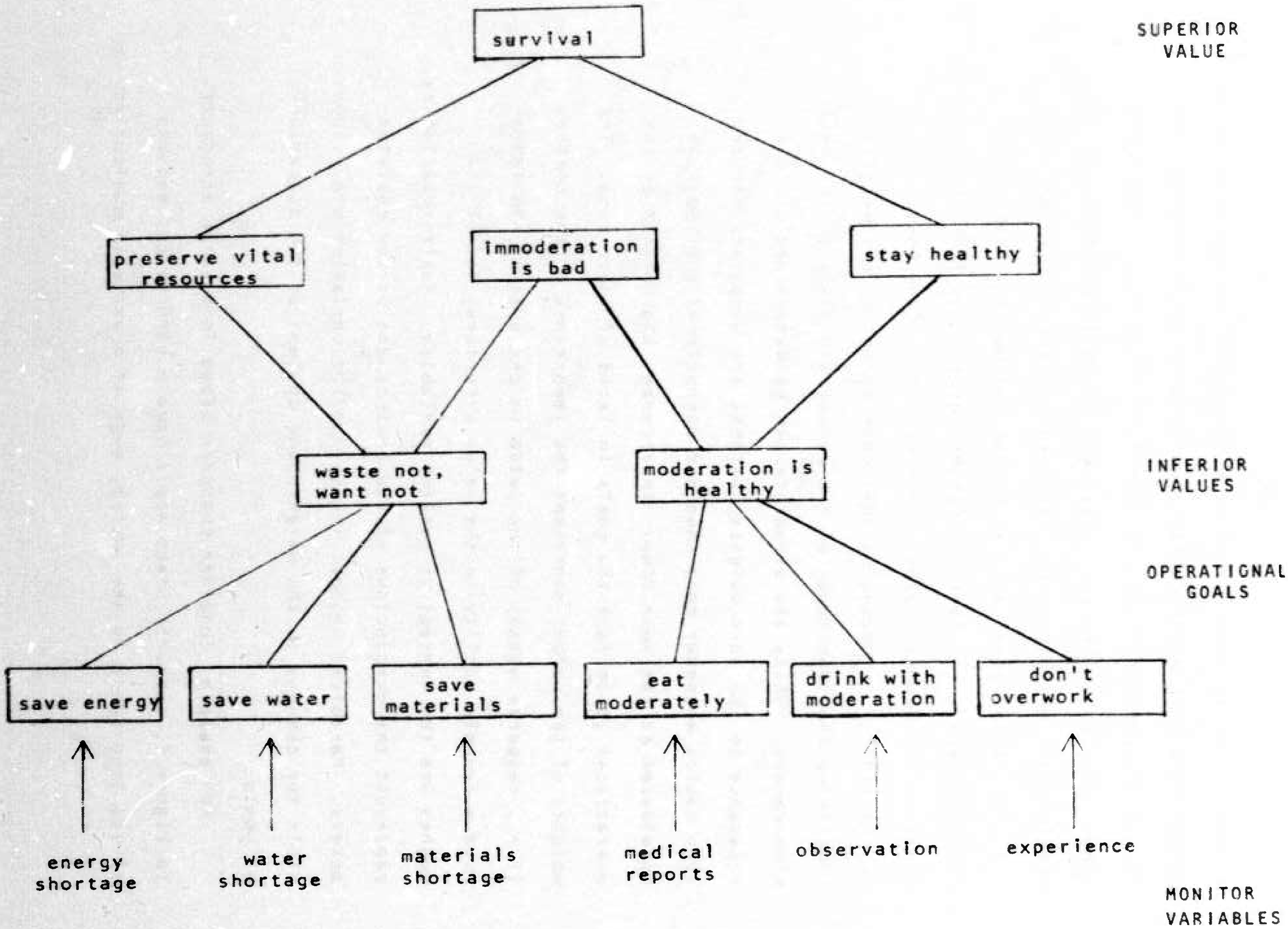


Figure 1 - Sample Norms Structure

fresh water supply indicated abundance. But in the case of abundance of water, the content (i.e., desired water conservation rate) of the operational goal would be smaller, as would the importance of that goal in relation to other goals in the system. As Bossel and Hughes have conceptualized it, changes in monitor variables cause changes in operating goals (i.e. specific desired levels of the goals) mediated through the value network.

In order for this formulation of the normative component of decision making to be used, the monitor variables, values, and goals of the country decision systems will have to be identified, along with the coefficients of weight and influence which relate changes in values of monitor variables to changes in values and goals. Once suitable values for the above quantities have been determined, the system must be evaluated in terms of sensitivity to small changes in the coefficients linking inputs to outputs. If it is the case that the system's output is very sensitive to the values of the coefficients, the representation may not prove workable, since the estimations will necessarily have a high chance of measurement error associated with them. Even if the problems associated with parameter estimation can be dealt with, the system must still be examined to determine whether or not the outputs (i.e., the goal changes, contents, and weights) look reasonable given the inputs and what is known about the system to be modeled. Until that analysis of the system has been completed, the

particular formulation of goal change must be considered provisional.

Assuming that the problems dealing with goal specification and change have been dealt with satisfactorily, the class of issues outlined above, dealing with the translation of goals and possible choices into decisions, must be confronted. The current state of the representation of the possible choices open to the decision-makers involves a spatial approach, where each dimension defining the space represents all of the possible values of a manipulable variable can be represented as a point in the space. While in principle there are an infinite number of points in the space, the number and character of the points or alternatives that a nation can choose is limited by technological boundaries, and within the set of technologically feasable points, we assume there to be a finite number of points.

While it is often the case in analyses of decision situations that decision-makers are defined as rational in the sense of considering all possible alternatives and choosing that alternative that maximizes their goals, when attempting to deal with real decision-makers' behavior, that assumption has shown to be of little help (Cf. Simon, 1955). In attempting to deal with the behavior of decision-makers, the concept of bounded rationality or satisficing behavior is introduced. It is argued that when decision-makers search for an alternative to their present policy, they 1) consider only a

limited number of possible alternatives; and 2) they only search for alternatives until an alternative decreases the difference between the projected state of the environment after implementation of the decision, and their preferred state to an acceptable level. Search for an alternative within the decision space is primarily a function of 1) prior experience; 2) dissatisfaction with the current policy; and 3) the distance, measured in the alternative or choice space, between the current policy and some alternative policy. In both works of Bossel and Hughes, and Nelson, Winter, and Schuette, the greater the dissatisfaction of the decision-makers with the current state of the environment, the further will be the search from the current policy point. If dissatisfaction is low, only those points close to the current policy will be considered. On the other hand, the greater the dissatisfaction is with the current policy, the greater the distance will be from the current point of the search. This does not imply that given a high dissatisfaction measure, the new policy choice will be a great distance from the current policy -- only that the search area will be larger. Thus, dissatisfaction and distance combine to identify those points or policies in the choice space that will be considered as alternatives.

While dissatisfaction controls the length of the search, the past experiences of the decision-makers influence the direction of the search within the choice space. As is illus-

trated in Figure II, the decision-makers may learn that movement along one dimension (C_2) may have more affect on the performance of the environment to be controlled then movement along another dimension. In this context, learning is indicated by the shape and position of the choice or alternative set. At the present time, work is being done on the method of determining the shape and position of the alternative set. Once it can be determined what the alternatives the decision-makers will consider in a given situation, the concept of choice can be explicated.

The current representation of the act of choice is conceptualized as a stochastic process. Drawing from the works of Nelson and Winter, and Nelson, Winter and Schuette, the possible choices are considered as states in a Markov chain process. Given the current policy, there is a vector whose components are the probabilities of considering a particular policy as an alternative to the current policy. The probability is not the probability of actually choosing the point as an alternative, but only of considering the point as a possible alternative to the current policy.

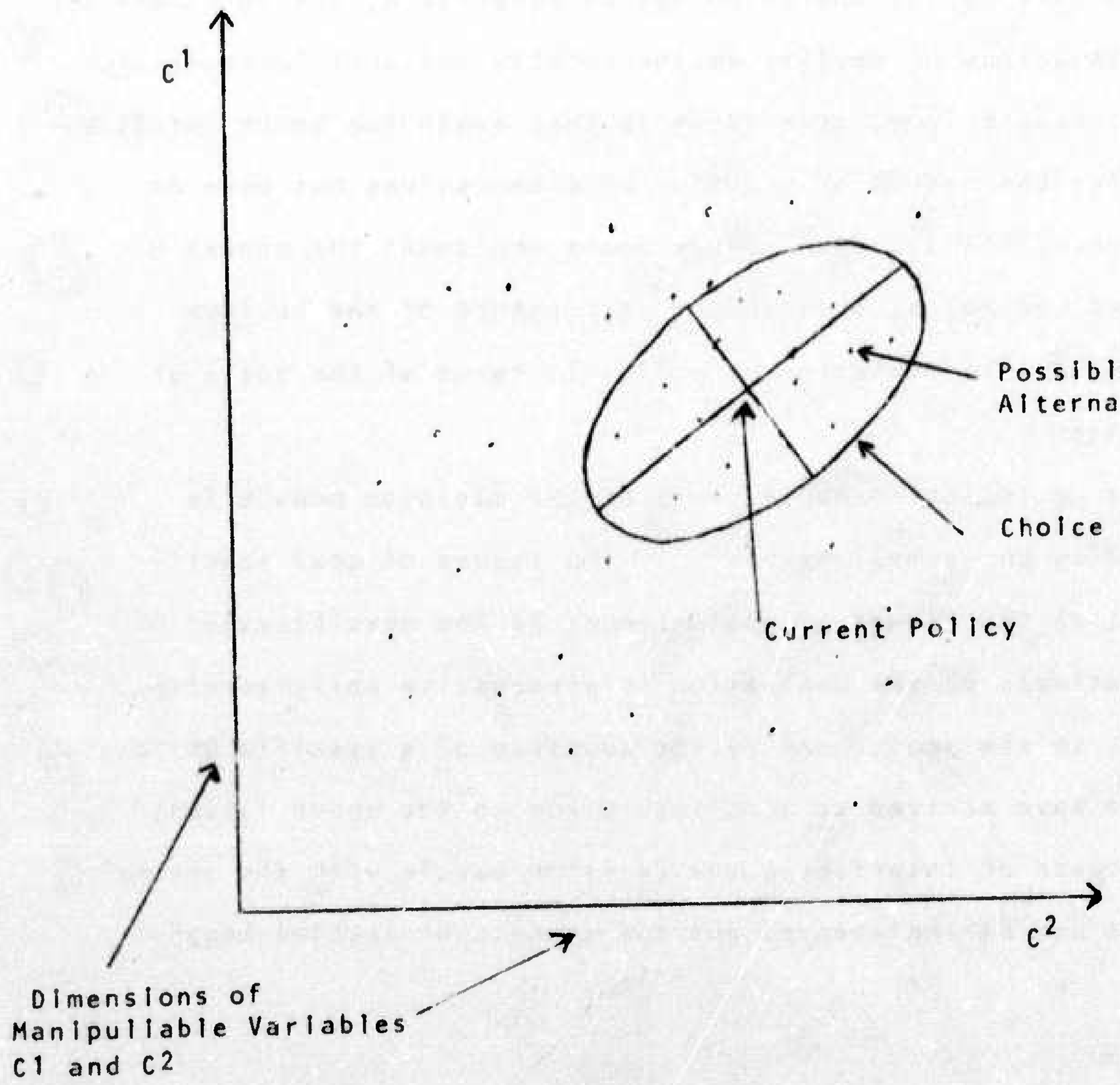
The last issue regarding the decision process to be dealt with concerns the process by which a policy is accepted or rejected as a feasible alternative to the current policy. One option would be to give the decision-makers full and accurate forecasting powers--but as was discussed above, the characterization of man as completely rational is not des-

criptive of reality. On the other hand, by denying the decision-makers any forecasting powers, the probability of consideration could equal the probability of adoption. In certain circumstances this latter operation may be acceptable, but in others it is as untrue of reality as the totally rational formulation. At the present time, this issue is just beginning to be resolved.

Once the method of adoption of alternatives has been decided upon, the decision module would implement the chosen mix of input variables, observe the performance of the various sectors, and re-evaluate the policy in terms of the goals of the system.

As we indicated above, work on the decision module is proceeding on several levels: 1) the issues of goal specification; 2) the issues of goal change; 3) the specification of alternatives; 4) the evaluation of alternative policies with respect to the goals; and 5) the adoption of a specific policy. Once we have arrived at some resolution to the above issues, the process of interfacing the decision module with the sector modules can be implemented and the process of testing begun.

FIGURE 11



C^1
C^2
Possible Alternative
Choice Set
Current Policy
Dimensions of Manipuliable Variables C1 and C2

REFERENCES

1. Bossel, Hamut H. and Barry B. Hughes, "Simulation of Value-Controlled Decision-Making: Approach and Prototype", Institut fur Systemtechnik und Innovationsforschung: Karlsruhe, Germany; 1973

2. Nelson, Richard R. and Sidney G. Winter, "Toward an Evolutionary Theory of Economic Capabilites", Institute of Public Policy Studies Discussion Paper #44: University of Michigan, 1972.

3. "Neoclassical vs Evolutionary Theories of Economic Growth: Critique and Prospectus", Institute of Public Policy Studies Discussion Paper #46: University of Michigan, 1973.

4. Nelson, Richard R., Sidney G. Winter, and Herbert L. Schuette "Technical Change in an Evolutionary Model" Institute of Public Policy Studies Discussion Paper #45: University of Michigan, 1973.

5. Simon, Herbert A., "A Behavioral Model of Rational Choice", Quarterly Journal of Economics, Vol. 69 (Feb. 1955), pp. 99-118.

An Analysis of the Goals of
Five Oil Producing Nations

Patrick T. Callahan
Project for Theoretical Politics
Ohio State University

Project Research Paper No. 14

The research described in this paper was supported by the Advanced Research Projects Agency Contract No. DAHC 15 73 C 0197.

This paper is part of a research project[1] attempting to develop long range forecasting models for foreign policy planning. In this paper an attempt will be made to analyze the goals of five nations: Iraq, Iran, Algeria, Libya and Saudi Arabia. The relevance of this enterprise to foreign policy planning is that the goals of a state determine what it would be willing to give up in negotiations and what kind of bait can be used to strike bargains with that state.

In this paper a goal will be understood to mean a desired state of affairs. A nation's goals are those of the top decision-making elite in the nation. It is assumed that to some extent the elite is a coherent group and the goal set is uniform for all members. The desired states may be either those which can be attained only with some change or those which are already achieved and only need to be preserved. Goals may be either specific or general quantitative targets or open-ended growth desires. Goals may be either ends in themselves or means to other goals or both.

The analysis will take two parts. In the first part the modal goal set of four of the five nations will be laid out. In the second part the relative importance of the goals will be assessed.

The identification of national goals can be approached in three possible ways. First, one can posit a set of goals which are held by all nations. Second, one can look at the

public statements of the nation's leaders for their assertions of their goals. Finally, one can reason from the goals defined by the other two methods to other goals which seem to be necessary for the achievement of the other goals.

The first method has been an extremely popular one in the literature of political science over time. Some examples of such an approach can be given. Morgenthau (1965:27) has offered the opinion that all nations are power seekers. Galtung (1966) has suggested that all nations seek certain goals in reference to their rank in international society on status dimensions, namely, that nation's seek to maximize their total rank and to equilibrate their ranks. Aron (1966) claims that all nations seek three goals: power, prestige and the advancement of some ideological position. Rosenau (1971) has hypothesized that nations seek to maintain the values of certain essential variables within acceptable limits, a process he calls adaptation.

The primary problem with these attempts to identify goals is that they refer essentially to foreign policy problems. This is understandable in view of the greater diversity of domestic needs and desires. There are perhaps no universally held national goals in reference to domestic policy. A major philosophical problem of these goals is that they assert statements as universally true which have not been tested against all cases in the universe. In other words, it is the classical induction problem. Although the truth of the statement for all other

cases makes it more probable that it will be true for later cases, it does not make it sure. It has to be tested against each succeeding case.

The second approach has also been extensively employed in the past. In this paper the primary source of goal statements are the reports in the <u>Foreign Broadcast Information Service Daily Report</u> (FBIS)[2]. This source has been augmented by some other primary documents. Some caveats about this source of data. First, although the editorial policies of <u>FBIS</u> are not published, there seems to be a bias toward reporting statements with some explicit foreign policy content. Second, because some national leaders are less verbal than others, there is an underrepresentation in the statements of some leaders. Third, the same result due to the differential degrees of rhetorical extremism used by the national leaders. As a result, the data base for this section of the paper is heavily skewed in favor of Iraq and Libya, and Saudi Arabia and Algeria are grossly underrepresented.

The third method is also very often used. It is also fraught with dangers. Two are most obvious. One is that there is great chance of error in deduction on the part of the analyst, especially in an area where the empirical premises are as questionable as they are in the social sciences. The other is that one is always on tenuous grounds ascribing to the decision-makers of the subject nations the goals which

seem necessary to the analyst because of the high probability that the decision-makers have not made the same calculations that the author has. Therefore, the goals revealed through a deductive process must be confirmed with other kinds of data.

We can begin this analysis by looking at some goals which seem to be commonly held by the decision-makers in four of the nations[3]. Perhaps the best way to begin would be to quote extensively from national spokesmen making as succinct as possible statements of the national goal sets. An unidentified member of the ruling Revolutionary Command Council speaks for Libya:

> The Libyan people ... have empowered the leadership to steer the phase of revolutionary transformation, to forge ahead toward building the all round Arab unity, to plan a socialism stemming from the Holy Koran, to enter the era of industry, to manage the agricultural revolution, to help erect a policy of positive neutrality and nonalignment and to come to the aid of the movements of national liberation throughout the world against the forces of e 1, oppression and aggression which many countries are still witnessing and which they are enduring[4].

Prime Minister Hoveyda offers a more detailed goal statement from Iran:

> One could sum up the main goals of the Fifth Plan in the following: the preservation of our rapid and continuous rate of economic growth combined with relative price stability and the maintenence of the external balance of payments; a more equitable distribution of the national income; the provision of productive employment opportunities for those seeking jobs; the constant increasing of the level of knowledge and culture and of public health, well-being and prosperity of the society; the preservation and improvement of the environment; the creation of a better balance between the various regions of the country from an economic and social point of view; the reform of the administrative set-up and the strenghtening of the nation's defense capabilities; full use of existing productive capacities and the elevation of the level of output in the production

> and supply of goods and services in both the public and private sectors, and finally, Iran's increasing share not only in international trade, including our own growing presence in new world markets, but also in other major economic and political processes in the world[5].

Al Bakr indicates a number of the goals of the Iraqi leadership:

> Foremost among these objectives was freeing the national wealth from the control of foreign monopolies ... Before you are the tasks of strengthening the national structure based on liberative, progressive and democratic bases. Before us are the tasks of building a national, pan-Arab and progressive front. Before us is the task of achieving the welfare of the toiling masses. Before us is a noble and pan-Arab duty requiring maximum endurance and sacrifice, a relentless and difficult duty. It is to confront the usurping imperialist-Zionist enemy

to liberate our holy land from his claws[6].

We can turn to Mr. Boumediene for statements pertaining to Algeria's national goals:

> "Algeria intends to be the mistress of its substrata ... For us, agrarian reform is a fundamental political choice. The state must intervene in order to transform the rural world in a radical manner ... We must produce for our internal consumption."[7]

In another speech he laid out three goals for the algerian revolution: "... the rehabilitation of the national economy ... freeing the national economy from all subjection ... setting up democratically elected assemblies at the heart of enterprises of an economic, social and cultural nature."[8]

This data allows us to assert the existence of a set of fairly generalized goals which are held by the leadership of the five nations. That economic development as one of those goals is fairly clear. All five leaders indicated an urgent need to modernize, rehabilitate, industrialize or speed up their respective economies. These statements indicate the desire to achieve economic development. A second goal which is apparent is to minimize the dependence of the nation on external sources of support. Basically, this is an autarchic urge to have the national economy capable of meeting domestic consumption needs so that imports are not

needed. A third goal which emerges is the achievement of humanitarian social goals. Generally, these include such things as the provision of housing, clothing, food and water for the citizens of the nation. A fourth commonality that needs to be pointed out is that each nation has a set of foreign policy objectives which it pursues. These foreign policy objectives are not homogenous across all the nations, but the fact that the nations each have important foreign policy goals is all that is important at this point.

With these four goal problems we can examine some of the common options that the national decision-makers have available to them, and some of the dilemmas and decision-problems they face. This analysis will establish a framework for the analysis of the goals of particular nations later.

In order to develop economically, it is also axiomatic that the industrial output produce adequate amounts of consumption goods so as not to depend on imports. Increased industrial output can be achieved through some combination of governmental investment and private investment. This suggests one additional goal and one choice to be made. The additional goal is to maximize public investment in industry. The choice to be made is whether and in what ways to allow or encourage private investment in the industry.

No matter how investment in industry is to be financed, the decision to industrialize necessitates certain other kinds

of expenditures by the government. Industry requires power, so the infrastructure must be established to supply factories with power. First, there must be electrical power, so electricity generating facilities and a power network must be established. Second, many industries require fuel such as coal or petroleum. In order to have fuel available, it must either be mined internally or imported. In either case there must be a network of road and railroads to transport the fuel to the factory. Roads and railroads are also required to transport the products of the factory to internal markets or to loading points for international commerce. The development of all of these is thus a goal of the leadership.

Another problem which faces the thrust toward industrialization is the securing of adequate numbers of workers, both skilled and unskilled. The solution to the problem of skilled workers depends on the investment policy taken. If private enterprise is involved, it will supply the skilled technicians and managers required at the plants. If the factory is a government project the government must look to the supply of technicians and managers. It can be safely assumed that no adequate pool of such persons exists within any of these countries. Therefore, extraordinary measures are required. There are three basic ways in which the skilled workers can be obtained. In the short-run they can be acquired from other nations through foreign technical assistance. More long run solutions involve the training of

persons. One way is to have a program of education, including either supervised training of persons in specialized skilled labors or more general education programs to create a pool of generally skilled persons who could be more easily adapted to a variety of tasks. The third option is to place relatively unskilled persons in jobs and have them acquire the skills through experience. This last option would be clearly modeled on the Chinese experience.

There are a number of trade-offs involved in the choice of a particular approach to the problem. The dependence on foreign technicians is clearly the most efficient in the short-run, but it is not a viable long-run solution and it conflicts with the goals of minimizing dependence on other entities. The option of educating a large pool of persons in general skills is perhaps the best long-run solution, but given the very low rates of literacy in the nations it provides no hope for short-run relief. The option of supervised training in particular skills is considerably faster than general education in providing skilled persons and is a better long-run solution than reliance on foreign technicians and managers, but has the immediate drawback of siphoning off trained persons from production jobs so that they can supervise the training of others. The last option is clearly the most inefficient in the short run and is only more efficient in the long run than the reliance on foreign technical assistance. However, it does have the strengths of putting warm

bodies into slots in an organization chart and providing some experience to a larger number of persons than any of the other options.

The other manpower problem posed by the necessity to industrialize is that of providing a pool of laborers for the more unskilled jobs that need to be done. This usually becomes a problem of persuading people to leave their agricultural pursuits in the rural areas and move to the urban areas. However, each of these nations has a severe unemployment problem so the pool of unskilled workers exists already.

The second goal identified was that there should be a minimum of dependence on external entities. This goal has two main thrusts: self-sufficiency and national control over economic production. Self-sufficiency has two main aspects: industrial and agricultural. Industrial self-sufficiency is a by-product of economic development in that the greater the economic development the greater the industrial self-sufficiency, assuming that industrial production is geared somewhat toward domestic consumption needs. Agricultural self-sufficiency means that the agricultural sector is able to supply adequate foodstuffs to meet domestic consumption needs. In these countries that would require the adoption of an additional goal: to increase agricultural output.

A number of different strategies exist for the expansion of agricultural output. One of them is to increase produc-

tion on land that is already under cultivation. Three techniques exist for increasing yields. One, fertilizers can be employed to improve the quality of the soil. Two, the work on the farms can be mechanized. Three, the amount of water on the crops can be controlled better through various irrigation techniques.

Two things are common about these three techniques. First, they are only appropriately employed in a large scale. This is because the equipment necessary to employ any of these techniques are capable of servicing a large area. Modern farm equipment can be used on small farms, but it would lie inactive for long periods of time, whereas on a large farm it gets used more extensively. In addition, it would be prohibitively expensive for a small farmer to purchase a large amount of equipment. Similarly for irrigation facilities and chemical fertilizers. The second commonality is that the techniques all require fairly heavy expenditures. This means that the government must make financial inputs into agricultural development, an additional goal.

A second strategy for increasing agricultural production is to increase the total amount of land under cultivation. The first way that this can be done is to move arable but inactive land into cultivation. The primary way to do this is to expropriate large estates with absentee owners and turn it over to active farmers. The second way that it can be done is to reclaim land from the desert. This requires the building

of dams or the digging of wells and the creation of irrigation networks to get water to previously desert land. This in turn requires expenditure by the government.

A third way to create agricultural self-sufficiency is to diversify agriculture. Prime examples are the creation of national fishing and dairy industries. Such an action involves making expenditures both in the creation of plant facilities such as fleets and farms and processing plants. In addition, it also requires specialized manpower, facing the leadership with a set of choices like those relating to industrial manpower needs.

A fourth way to move toward agricultural self-sufficiency is to reduce the production of surplus generating produce and shift the resources thus saved to the production of other kinds of foodstuffs.

The decision-makers thus have a number of contraints and options in achieving agricultural self-sufficiency. They have to encourage larger modes of organization in the agricultural sector. It can do it in three ways. It can encourage the formation of cooperatives in which a number of small farmers share the more advanced technology (tractors, combines, ets.) among themselves, thereby reaping the economies of scale; or it can encourage private enterprise (agri-business) to move in and run large sections of the agricultural sector. The tradeoffs are significant. The first two require massive inputs of government cash. The last would cost the government little or nothing

but would involve the displacement of numbers of rural persons and would require the additional penetration of the economy by foreign companies. Displacement of persons would be terribly unhumanitarian. And the penetration of the economy by foreign companies would be seen as counterproductive to the goal of minimizing dependence.

In addition to these choices in altering the organization of agriculture, the decision-makers have some options in financing the investments involved in some of the approaches to expanding agricultural output. Some, such as provision of irrigation facilities, simply require massive outlays of money. But the creation of fishing and dairy industries and the like are capable of more flexible solutions. Most notably, it is possible for a nation to seek out a possible partnership with another nation and form a jointly owned, managed and financed operation. This option requires a smaller input of government funds and allows economies of scale, but also abandons to some extent the goal of minimizing dependence.

The second main thrust of the goal of minimizing dependence was to exert national control over economic production. The reason for this is that where private, external entities control some area of economic activity they are able to make decisions without necessarily paying great heed to the effects on the national economy, and in some cases they may be able to use the control as a political weapon to influence national policy. There are a number of options available to the national

leadership in exerting control over the economy. At one extreme is full nationalization of enterprise. This can be done with varying degrees of compensation paid. Less extreme is to have a partial takeover, by forcing the enterprise to sell the government enough stock to insure it majority control of the enterprise. Another option is to negotiate some form of governmental participation in enterprise decision-making, either through stock purchases or veto options or mandatory participation. The number and variety of such possibilities are relatively limitless.

There is a major dilemma posed for national decision-makers in exerting control over the economy. If they opt for one of the more severe forms of getting control, they will have more complete control. However, in so doing they will usually precipitate a very severe economic conflict with potential disastrous economic effects, they risk the loss of the technicians and managers who run the enterprise, thereby placing further strain on their already shallow pool of technicians and managers, they risk losing the chance of further capital investment by the company or other companies placing extra demands on the governmental budget, and they create an environment that may reduce private investment in other sectors of the economy, thereby slowing industrialization and placing an extra burden on the government development budget. On the other hand, the more severe forms of control, nationalization or majority control, do

have the advantages of more fully meeting this goal of minimizing dependence. Further, they can also benefit the governmental budget if the enterprise is a profitable one by allowing the government a greater cut of the profit pie.

The third goal, the achievement of various humanitarian goals, is actually a heading for a potpourri of subgoals. The most significant of these are as follows. One of the basic human needs is shelter, preferably of a decent kind. A governmental goal would be to make sure housing is supplied. Another basic need is to have medical care. The governments goal would be to insure the provision of medical services. Subgoals here would include building hospitals and clinics, acquisition of medicines and acquisition of trained medical personnel, either through education of natives or through foreign assistance. Another humanitarian goal would be for the government to take actions to make sure consumer goods are available to the citizens. Another humanitarian goal is to eradicate poverty, which can be achieved through income redistribution and the reduction of unemployment. Another way to fight poverty in these countries is to ease the condition of the peasant by seeing to it that he has enough land to be able to earn a decent living. Thus land reform would perhaps be a major humanitarian goal. Another significant goal would be to eliminate illiteracy, suggesting an ancillary goal of providing education to the populace. This goal would entail the building of schools and the allo-

cation of educated persons to the schools as teachers. Finally, humanitarian impulses would seem to necessitate the provision of certain crucial social services to the public. Four outstanding ones would seem to be the building of roads, the provision of water, the construction of sanitation facilities and the creation of an electrical network.

Finally, the fourth category of goals, foreign policy goals, seems to necessitate three subgoals: the creation of a diplomatic network, the provision of financial and military assistance, and the maintenance of an armed services establishment.

Another significant subgoal derives from the goal of minimizing dependence. In order to operate industries the nation must have various raw materials. Some of these are fuels and some are important minerals, such as copper and iron or steel. The nation must either import them or produce them domestically. Since domestic production would be tantamount to decreasing dependence, a new goal has been uncovered: to exploit the nations mineral resources.

One very significant thing has been in common about all the goals and subgoals discussed so far. They all eventually lead to a necessity for the government to spend money. But the money supply is limited so these governments are placed under two constraints. First, they must make choices about what expenditures are most important to them. They must

have a set of priorities. The second constraint is that they must have an additional goal: they seek to increase the government income.

The government has a number of ways in which it can get new money to spend. Because of its importance in their economies, measures relating primarily to oil will be treated separately. In non-oil sectors the most obvious way for the government to get additional money to spend is through an increase in taxes, the traditional approach of monetarily pressed governments since time immemorial. Taxes include programs which are called taxes and those which are not but which require contributions to the government, such as mandatory savings programs. Another way to increase government revenue is to institute voluntary programs in which the public makes an input. This includes savings programs, selling stock in national enterprises and selling bonds on government projects. A third way is to seek increases in foreign assistance, where foreign assistance is relatively untied block grants of money. The next technique operates mostly to take some of the burden for development projects from the development budget. That is to get long-term low interest loans. A fifth way is for the government to sell more of the output of public industries. The sixth and seventh ways of bracing government finances involve alternative ways of financing dealings with external entities. The idea is to conserve foreign exchange pools.

This means that alternatives to hard currencies must be employed in making exchanges in the international market. There are two ways of doing that. One is to go to a bartering arrangement in negotiating trade agreements. The other is to attempt to pay off debts with goods. For example, supplying a certain amount of petroleum in return for the liquidation of a debt for a loan. The next two options involve increasing the flow of foreign currency into the national economy. By doing that some will be siphoned off by the government. Two ways of getting such an increased flow of foreign currency are to promote tourism and to increase exports. A final way for the government is to invest funds in private enterprises elsewhere. Then the dividends will provide financial resources in the future.

There are two ways in which the government can deal with financial problems by reducing the burden on the budget. The first is for it to encourage private investment in the economy. That would take some of the burden of industrialization off the government. The other is for the government to join other governments in joint financing of projects so that the cost will be reduced for each.

Finally, we can see how these goals relate to the most important sector of the economy, the petroleum sector. Since petroleum is so outlandishly important the viability of the economy and the government both depend on events in that sector. Therefore, it is one of the goals of the nations to gain con-

trol of this industry. The process of gaining control is dictated by the fact that petroleum is a magnificent profit-maker. To the extent that the government owns the petroleum facilities, to that extent it is not required to share those profits with anyone. And to that extent it can mitigate its own financial difficulties. Thus the first goal of these countries is to extend national ownership of the petroleum sector. The options available to the leadership are the same as for other areas of the economy and the constraints are also similar.

The role of petroleum as a revenue producer generates an additional goal, that being to maximize government revenues from petroleum. Nationalization as a means to that end has already been discussed. To the extent the petroleum is not totally owned and controlled by the government the revenues can be increased in any one or any combination of three ways: the tax rate on the oil companies can be increased, the price of oil can be increased, and/or the total amount of oil sold can be increased. The first can be done relatively autonomously by the governments, the same for the second in a sellers market. But the third necessitates the adoption of additional goals. First, there must be expanded production. Expanded production entails that the discovery rate of new petroleum reserves be accelerated, which in turn entails that an adequate number of skilled persons be available to the managers of the petroleum sector. Sources of such skilled oil prospectors are

similar to the sources of skilled manpower for all sectors. In addition to finding new petroleum deposits, expanded sales also requires that the petroleum delivery system be expanded. This means that new wells must be dug, new pipelines built and possible new tanking facilities developed: harbors modernized and new tankers built. Financing these projects is once again a problem, the main options being either to have government financing or private enterprise financing.

In addition to expanding its revenues through control and manipulation of the crude oil aspects of the petroleum industry, the oil producing countries can also increase their revenues by getting in on the refining aspects of the petroleum business, allowing them to sell petroleum products and reap a potentially greater profit than merely the profit from the sale of crude oil. So another possible goal would be to create a petrochemical industry.

Once again, the goals of the decision-makers and the constraints in the system seem to place the government in a dilemma. On the one hand, their participation in the exploration for oil and the management of facilities, in addition to their financial help, would be greatly appreciated. If the government institutes policies that are too severe it may prevent the oil companies from being cooperative. In addition, if the oil companies are the primary customers of the oil, which is the case with crude oil, harsh policies may trigger a boycott of their oil and cause severe short term

damage to the budget and to development plans. On the other hand, if the government policies are more severe the sooner it will manage to get control or a significant increase in revenues, with all the advantages that suggests.

Now that the internal logic of goals, as reconstructed by an unexpert outsider, has been explicated, it is now time to turn and see how the decision-makers of each nation see the situation and how they react to the dilemmas presented.

LIBYA'S GOALS

In the few years since the present regime came into power the Libyan Arab Republic has established itself as one of the most active revolutionary actors on the world scene. This revolutionary bent is reflected in the extreme formulation of its foreign policy goals, the avidness with which they are pursued, and the intensity of the regime's actions in securing control over the national economy.

The fundamental link in Libyan revolutionary ideology is the apparently whole-hearted belief in the existence of an Arab nation. This Arab nation is inflicted by a number of malaises, the most notable being the political division of the Arabs into "regions" which we call nation-states, the occupation of Arab territory by Israel, aggression against the Arab people by the dark and nefarious forces of imperialism and the underdevelopment of the Arab nation. Libyan foreign policy is fired by the urge to eradicate these evils. Thus Kaddafi has asserted the new great aim of the Libyan Revolution is to procure the "freedom of all Arabs and the unity of the entire Arab nation."[9]

A fundamental perception of the world held by the Libyan leadership must be understood if Libyan ideology is to be understood. The Libyan leaders perceive the present Arab states as being small, weak entities in a world dominated by large powers. So long as the Arab states are divided, they will not be able to resist the pressures from these large

states. Their autonomy will be fraudulent since they will be controlled through subtle means by powers they are unable to resist. Thus Kaddafi has advocated a policy of positive neutrality, meaning no alliances with major powers, for when such alliances are formed "the Arabs have lost their independence."[10] However, a united Arab nation would have the population and the wealth necessary to preserve independence of the Arabs.[11]

To this end, the Libyan regime has engaged in a series of actions to bring about Arab unity. The most famous of course is the unification plan between Egypt and Libya. In this problem area the Libyans have demonstrated that their urge to bring things to fruition is greater than that of the Egyptians. At another time Kaddafi offered to Mr. Bourguiba the leadership of a unified Libya and Tunisia.[12] The urging of Arab unity is a constant and tiresome theme in their public speeches. In addition, Kaddafi has evolved a theory of Arab unity which is worth quoting at length. He begins by positing three mechanisms for producing unity.

> The first method of Arab unity is the ideal one which Abd an-Nasir advocated: the unity of the revolutionary regimes which believe in freedom, socialism and unity, which will unite when the revolution takes place in their respective countries.
>
> The second method of reunion is that we should abandon the ideal method for

> achieving Arab unity and try to bring the Arabs together within the present regimes--the monarchy, the republic the amirate, the feudal state and the socialist state.
>
> The third method of Arab unity is that of conquest--united Arab forces should conquer Arab countries, in order to achieve unity by force.[13]

His assessment of the situation is that the second method will not work and the first cannot be depended on, so he offers the following strategy: ...should the regimes fail to unite themselves in their present form, then revolutions should break out to achieve Arab unity. A revolutionary tide and conquest should break out to achieve Arab unity. All this area must flare up to achieve an Arab unity.[14] For this reason the correspondent for the Economist observes that "President Kaddafi of Libya does not conceal his hopes or his ambitions. Libya is to do for the Arab world what Prussia did for the unification of Germany."[15]

The approach of the Libyan regime to the solution of other foreign policy problems has also been active. In reference to the Israel problem it has been reported that Libyan commandos were fighting along with the Palestinian Feyadeen[16] and Kaddafi has offered to open Libyan territory

and to pick up the tab for the training of any Arab who was willing to join the battle.[17] The Libyan regime has also confronted the perceived imperialist threat with aggressive action by supporting financially the revolutionary enemies of the so-called imperialist powers. Money has been given to Malta,[18] to Uganda,[19] to the Philippine Moslems,[20] to Equitorial Guinea,[21] to the United Arab Republic,[22] to Syria,[23] to South Yemen,[24] and to Black Muslims in Chicago.[25] Threats have been made to send armies into the Spanish Sahara to generate a revolution.[26] In all, the regime has given about $1.5 billion in aid to the revolutionaries of the world.[27] And it has directly acted against the "imperialist" powers by nationalizing their petroleum facilities as political moves.[28]

The place of its foreign policy goals in its hierarchy of desires has been made clear by the Libyan leadership. The amount of weaponry purchased, the amount of financial aid given, the amount of activity devoted to foreign affairs all suggest that the regimes most important goals are the foreign policy ones. This supposition is supported by the direct testimony of Mr. Kaddafi:

> "Brothers, we cannot act as people did in the past when, on the pretext of domestic interests, they sought to evade national duty toward their nation. Brothers, we assure you that domestic problems will never affect our attitude toward Arab

reality and destiny and toward the enemies of Arabism."

As a caveat it should be noted that some evidence does exist to indicate that the Libyan fervor in foreign policy is not as great as the rhetoric may exist. First, there seems to be a concern with the importance of Libya in the Arab camp and an intention to advance that importance. Thus Kaddafi had complained long ago about the exclusion of Libya from the central planning councils of Arab strategy[29] and that was the reason given for the withholding of Libyan military support in the recent war. Second, much of the financial aid may be largely symbolic. The Economist reports that Libyan assistance did not go to the PLO central fund, and that money which was given to splinter organizations did not have maximum benefit because the Libyans caused currency difficulties over the transfer of contributions.[30]

In the area of domestic affairs the goal of minimizing dependence has to be seen as a significant one for the Libyan leadership. In the oil sector the regime has undertaken a series of significant actions to assert control, including the nationalization of the largest producers. One could question the relationship of these actions to the goal of minimizing dependence, given the political impetus to nationalize, were it not for the history of Libyan nationalizations in non-petroleum sectors of the economy. In 1971 and early 1972, the following actions had been taken: all minerals

have been declared state property,[31] road transport was nationalized,[32] National Supplies Corporation set up to control imports and marketing of essential commodities,[33] four insurance companies nationalized,[34] state owned construction company established,[35] all three oil distribution companies amalgamated into one,[36] establish General Agricultural Committee to run state owned land on a commercial basis,[37] create commission to control import and sale of agricultural machinery,[38] the medicine trade was nationalized,[39] a state tobacco authority created to control importation and quality of production,[40] the machinery companies were nationalized.[41] The record in this area is quite breath-taking.

The extensive record of Libyan nationalizations indicates that it probably is willing to forego private industry as a source of assistance in development and rely on the governmental budget. The reason for that decision is likely that the government has not generally been pressed for finances, due to the money-making power of petroleum and to the small Libyan population. The small population puts a natural limit on the capacity of the nation to adopt expensive development programs. Moreover, various bottlenecks make it impossible for the economy to absorb investment above a certain level.

Turning to the ways that Libya spends its money, a number of insights into their priorities can be seen. The relevant data on their relative expenditures are given in Table 1. It would appear that the breakdowns in the budget

can be classed into three groups according to the amount allocated. Four areas are allocated significantly more than the others, those being agriculture and agrarian reform, industry, transportation and communication and housing and utilities. Then there is a group of allocations indicating middling priority: petroleum, education, electricity and local administration. Then comes a set of low priority items: public health, labor and social affairs, information and culture, projects reserve, economy and tourism, and planning and management.

However, this does not accord with our breakdown of national goals in the first part, so we need to look more deeply into the problem. While the titles of the areas in the budget are sort of opaque concerning what they refer to in program terms, we can make some reasonable inferences. First of all, those goals which were classed under the humanitarian banner are relatively dispersed throughout the budget. If we sum up the categories housing and utilities, education, public health, and labor and social we see that at least 25.5% of the planned allocations and at least 31.0% of the 1972-3 budget allocations go to areas that are clearly humanitarian in their intent. In addition, that is likely to be a low estimate since some of the funds going to agrarian reform and local administration are likely to be intended to serve humanitarian purposes. So humanitarian goals are a significant part of the Libyan goal framework.

Table 1: Percentage breakdown of Libyan expenditures, by problem

	3 year plan	1972-3 budget
Industry	15.0%	13.1%
Agriculture & Agrarian Reform	14.2	14.4
Transportation & Communication	14.0	12.8
Housing & Utilities	10.9	14.1
Petroleum	10.6	8.6
Education	9.3	10.9
Electricity	8.8	8.7
Local Administration	8.5	8.2
Public Health	3.9	3.8
Labor & Social	1.4	2.2
Information & Culture	1.3	1.7
Projects Reserve	1.0	.2
Economy & Tourism	.7	.8
Planning & Management	.4	.2
Total	100.0	100.0

Another modification that might be made in the apparent relation of things would be the relationship of agriculture and industry. In the budget data they are very close in the amounts allocated. But a closer inspection of the planned projects in the industrial area indicate that agriculture is far more significant because many of the industrial projects actually are food processing projects and serve the purpose of making Libya agriculturally more independent. Thus of 29 industrial projects under contract in October of 1972, at least 8 were involved in the creation of food processing facilities.[42]

Another important aspect of the industrial development program of the Libyan regime is that it's orientation is primarily toward small industries. Of the projects under contract in 1972, five involved the clothing industry.

Another thing about the industrial program is the concern with construction. Of the 29 projects, four were concerned with that industry. Also, combined with the emphasis on food processing and with clothing production, the construction material industry indicates that one of the main purposes of the industrial development of Libya has been to produce for domestic consumption and to not be too concerned with producing for export.

Agricultural strategy appears to be mainly related to two things. First, the agricultural part of the development budget is largely focused on four main regional development

projects: 1) the al-Jafara plain, 2) Jebel al-Akhdar, 3) al-Kufra and al-Sarir, 4) al-Shati, al-Ajal and Traghen. In addition, preliminary studies have been contracted for the improvement of 20,000 hectares of pasture land in Sitre region and for a climatic and hydrological surveys of 20,000 hectares in Wadi el-Ramel region.[43] Details of what is involved in these agricultural development projects are scarce, but for the Jebel al-Akhdar region the building of dams and reservoirs and an atomic powered desalination plant are intended to aid in the reclamation of land from the desert.[44] This suggests that the primary goal is to increase the amount of arable land. This suggestion is fortified by the actions of the Minister of Agriculture and Agrarian Reform, who called on Libyans who owned capital to invest in agricultural projects for the expressed reason of increasing the amount of area under cultivation.[45]

The second aspect of agricultural strategy also involved an increase in the territory under cultivation. Specifically, the land owned by Italians and Jews, much of which was apparently inactive, was expropriated and distributed to Libyan peasants.[46]

The regimes attitude toward the capitalization of agriculture is not entirely clear. Although a commission has been set up to control the import of agricultural machinery, it is not clear how that machinery is to be used, in view of

the fact that peasants are not discouraged from keeping down on the farm and that there is no apparent policy of creating rural cooperatives. A distinct possibility is that the General Agricultural Committee, alluded to earlier, will use the machinery on lands reclaimed from the desert.

Also in the agricultural sphere, the regime has been pursuing a diversification of produce through the creation of a fishing industry. It has set it up jointly with Tunisia.[47] Libya has built three ice factories and is in the process of building canning factories to supplement the fleet.[48]

In the petroleum sector the behavior of the Libyan regime has been eratic. It has made some policy moves toward increasing oil revenues but has also made some which went in the opposite direction. At least four times in the time period 1971-1972 the regime has demanded either an increase in the posted price and/or the tax rate on crude oil.[49] On the other hand, it has also required the petroleum companies to reduce production a number of times.[50] What this suggests is that so long as Libya is in good financial straits it chooses to conserve its petroleum reserves and maintain oil revenues through price and tax increases. One can surmise that if the situation changed and Libya became in a financial bind, the strategy would change and conservation of reserves would be jettisoned in favor of increasing revenue through increased production.

Also, Libya has not appeared too eager to get the full

cut of the oil profits through nationalization. Although seeking to exert control over the oil companies and to eventually take over full ownership, the Libyan government has only nationalized completely for blatantly political reasons. British Petroleum was nationalized in retaliation for Iran's take over of the Tumbs Islands. American concerns were nationalized this year because of American Middle East Policy.

A probable explanation for this fact is that the Libyan regime seems to have made a conscious choice to use the petroleum companies to accomplish tasks for them. Thus the companies were put under pressure at various times to invest in petroleum projects, especially exploratory drilling, but also to invest in agricultural, industrial and mining ventures.[51] The reason seems to be that the Libyan regime has decided that it needs the technical skills possessed by the oil companies more than it needs the increased revenues or satisfaction of owning the petroleum companies.

The final comment which needs to be made in reference to the petroleum sector is that the regime does seem to place some value on developing national control over the finished form of petroleum products and on having a share in the upstream facilities. They have plans for a gas complex at Benghazi and a methanol plant at Brega. They have also built a pipeline to a Sudanese steel mill[52] and have invested over \$48 million in a tanker fleet.[53] Thus a goal of the

regime seems to be to create an integrated petroleum industry in Libya.

Turning to the main areas of bottlenecks in development, infrastructure and manpower, there are what appear to be concerted efforts to overcome them. One of the single largest items in the development budget is for roads and another large project is in development of ports. The data do not allow a breakdown of these expenditures in terms of their relative impact on industry, agriculture or petroleum, although the allotments for ports is probably more industry and petroleum oriented. Nor do the data indicate if "enough" is being spent on these areas, although given the concentration of population and economic activity near the coast it is probable that supplying the country with adequate roads is an easier task than in a country where things are more spread out.

In manpower, the regime is pursuing a number of approaches. In order to meet their immediate needs they have adopted three techniques. The most important has been to seek the assistance of foreign technicians, with a variant of seeking to hire foreign technicians (from Kuwait and Malta). The second most important has been to seek to keep technicians associated with private enterprise in the country. The third and most imanginative, and also least frequent, is exemplified by the deal with a British company in which the company and the government would both put up capital for a petrochemical complex with the British

firm helping to operate and market the finished product.[54] There is only one case of long-term needs being met through training of Libyans by foreign technicians so in that respect the manpower orientation of the regime is very much short-run. On the other hand, they also have long-run concerns, and the importance of these are reflected in the education budget. By far the most important part of the education budget is allocated to elementary schools. The next largest part is in the Libyan University. But since the university is very much oriented toward the practical aspects of life rather than the liberal arts, the university allocation can be considered as a vocational training allocation. All this suggests that the manpower goals of the regime are to tread water on short-term nbeds, to develop a large pool of literate citizens and to funnel them as quickiy as possible into skilled occupations through vocational training.

In the area of financing development, the preferences of the regime are fairly clear. They prefer to finance projects through internally generated funds. Where that is inadequate they prefer to increase taxes. mostly on the petroleum companies but not totally. The traditional Islamic wealth tax was reimposed[55] and pressure was brought to bear on persons to make voluntary contributions to development projects.[56] In line with their phobia against dependence on external entities, the regime did not resort to financing any projects through long-term loans or through foreign aid. It dealt predominantly in

cash, using barter arrangements only once, and then due to a pinch created by the decrease in sales due to the British Petroleum conflict. In terms of long-range financial goals there seems to be no interest in investment in projects in other countries, the only move made in that direction being some investments in Malta which were more foreign aid than economic decision.

Saudi Arabia's Goals

Of the five countries treated in this paper, Saudi Arabia is the only one whose leadership does not claim to be involved in a revolution. Saudi Arabia is referred to as a conservative nation by its friends and as a reactionary one by its enemies. Its goals are appropriate to a nation so perceived.

Saudi Arabia's two main goals are to preserve a balanced budget and to achieve a pair of foreign policy goals. The foreign policy goals are to aid the Arab states bordering Israel and to maintain influence over events in the Persian Gulf. Support for this assertion is found in Saudi behavior during a financial crisis following the 1967 Arab-Israeli war. Saudi Arabia committed itself to providing massive assistance to the Arab states on the front line. This aid came out of the General Reserve Fund that had been built up through cautious spending policies. At the same time a conflict developed with the Syrians over the Trans-Arabian Pipeline (Tapline) and no oil could be pumped. Therefore, the General Reserve Fund could not be supplemented with new funds and quickly eroded. By 1969 the Fund was exhausted, and the government decision was to cut back on allocations for developemnt projects, continue in defense development, meet its foreign aid obligations and impose some new taxes, but not to go into debt.[57]

Budget data also support this assertion of priorities.[58]

Allocations for agencies of the government interested in security (Ministry of Defense, National Guard, Ministry of Internal Affairs, and General Intelligence) have consistently gobbled up over 30% of the budget and in most years have gobbled up more than 40%.[59]

The next two most favored goals are indicative of the development strategy of the Saudi Arabian regime. The strategy seems to be to build up the national infrastructure so that an environment for modern industry and agriculture to flourish exists, but not to directly build up those sectors to any great degree. Thus the second most heavily budgeted sector of the economy is the communications sector, which receives over 10% of the budget. The lion's share of the communications budget goes to road building. In 1971 (1390-1391) there were a total of 1,286 kilometers of road under construction and an additional 5,788 were in the planning stage.[60]

The next highest allocation has gone to the education ministry, ranging over the last four years between 6.5%-10.7% of the budget and increasing in the last two years. The stated purpose of high educational expenditures is to provide needed manpower for future development. Most of the educational expenditure appears to go into primary and secondary education. The government has also instituted an anti-illiteracy program to be implemented over a twenty year period.[61]

A major change in the budgeting behavior of the Saudi Government that may be significant is the rapid increase

of the Ministry of Foreign Affairs:

"Iran's spectacular economic growth over the past eight years, which shows no sign of letting up, is largely the result of two factors: far-sighted government policies which have created the necessary physical infrastructure and business confidence, on the one hand, and an active, relatively unfettered class of businessmen and industrialists, on the other. The relationship between the public and private sectors in Iran is an unusually amicable one, with the government responsible for heavy and basic industries and setting overall guidelines; and free enterprise, both domestic and foreign, hard at work in most spheres of economic activity."[129]

Iranian projects in the area of heavy industry include the Aryamehr steel mill near Esfahan, a heavy machinery plant at Arak, an aluminum smelter at Arak, a tractor factory at Tabriz and a machine tool factory at the same place. Private investment activity in Iran in the period 1967-1971 resulted in the creation of 500 factories in such areas as rubber, paper, cement, glass, electrical goods, textiles, food processing, and others.[130]

Iran has declared there to be three main purposes in its industrialization drive: self-sufficiency in consumer goods, production of capital goods and production of industrial goods for export.[131] In order to encourage private investment the government has offered what it calls "generous tax holidays, bonuses and other incentives."[132] As an additional encouragement to private enterprise the government has avoided nationalization actions against private enterprise outside the petroleum sector, and its recent actions there were quite moderate compared to those of the other Arab nations.[133]

Another aspect of economic development to which the Iranian leadership has devoted considerable attention is agriculture. Iranian strategy in agriculture has been to move to modern methods of farming. This has been carried out in a number of ways. The amount of land under cultivation has been increased through an extensive program of dam-building and subsequent irrigation of the land. So far, 611,000 hectares of land have been bought under irrigation as a result of the building of seven dams, an additional 84,000 hectares will be irrigated as a result of two dams under construction and 185,000 more will be as a result of four dams in the planning stage.[134]

In order to shift the agricultural sector to a large basis, three steps have been taken. First, farmers cooperatives have been created. So far there are close to 8,000 cooperatives organized into cooperative federations. There are facilities available to grant credits to the cooperatives.

A second approach has been to create government-owned farming corporations. There are 27 such entities which farm over 105,000 hectares of land. The third way that large scale agriculture is sought is through the encouragement by the government of the establishment of agri-business by private corporations.

Both industrialization and agricultural development have been promoted through rather extensive governmental programs of infrastructural creation. Except for defense the expenditures of the government on Communications and Telecommunications in the largest single item in the general budget, constituting 12.8% of the total. The lion's share of this appears to go into road and railroad construction, both major paved highways between industrial and commercial centers and feeders roads for agricultural use. In addition the government allocates a significant amount (4.2% of the general budget) for electrical supply, an allocation which appears to be independent of the expenditures involved in establishing generating facilities in the major dams.[136]

The placement of economic development as the second most important goal of the regime is at least debatable because the regime also allocates a great deal of resources to the humanitarian goals that it pursues. The second highest non-military item in the budget is education, at 10% of the general budget. And 10.7% of the budget is allocated to other aspects of social affairs.

But it is plausible to argue that this emphasis on social needs is partly illusory. The government places great emphasis on education partly because of the perceived importance of education to economic development. Thus expenditures on education are somewhat like expenditures on development. Furthermore, the government is making great efforts to reorient education at the secondary level away from "theoretical secondary education"[137] toward vocational and technical education. And at the level of higher education there is an explicit intention of producing persons with the skills to fill highly specialized manpower needs in the economy.[138]

Despite this caveat the commitment of the regime to the attainment of humanitarian ends appears to be quite significant. The two areas of greatest concern seem to be the health area and social insurance. The construction of hospital facilities and urban clinics have been the main thrust of the government health care program. The social insurance program covers over 800,000 workers.[139] Additional programs under the social acitvities area include such things as sewerage, water facilities, fire-fighting, home loans, village electrification, rural road work and provision of recreational facilities.

The government does not seem to place too high a value on provision of consumer goods to the public, as evidenced by their emphasis on industry with export potential (the 1970's have been proclaimed the "Export Promotion Decade") and by the governments use of importing consumer goods as an anti-infla-

tion weapon rather than as a means of promoting public welfare.

The petroleum sector is a major concern of the government. As the Economist[140] has observed

> "... the Iranians reckon that they have 25 years' grace before their oil reserves run out or are superceded by new forms of energy. By then Iran has got to be well established as an exporter of 'sophisticated industrial machinery' as the Prime Minister, Mr. Hoveyda, puts it."

What this means is that Iran has to wring out of the petroleum sector what it can while it can. Their approach has been to attempt to maximize the amount of petroleum exported and the price of that which is exported. In order to increase the amount of petroleum exported the regime has attempted to keep the private companies of the oil consortium involved in the extraction of crude oil by not participating in the participation deal worked out by Mr. Yamani of Saudi Arabia. Rather, it attempted to get the oil companies to increase the amount of petroleum they could pump. In addition, the regime has invested heavily in upstream capacity in order to increase the flow of crude oil. It has initiated a project to build a pipeline from the oil fields of southern Iran to the Turkish port of Iskanderun in order to circumvent the problem of getting oil to Europe when the Suez Canal is closed.[141] It has created a number of new ports (notably at Bushehr and at Bandar Abbas) and has created new facilities for loading tankers off-shore

in the Persian Gulf.[142]

Actions to increase the cost of petroleum include actions to increase the posted price and the tax rate on oil produced by consortium companies and to increase the price of oil sold by NOIC.

In regards to the two main bottlenecks in the Iranian development program, manpower and finances, the government handles them fairly well with one policy, that of encouraging private investment. By doing that it uses the financial and manpower resources of private enterprise to free indigenous manpower and money for other purposes.

Other aspects of Iran's financial strategy warrant attention. It's primary source of funds has been and is increasingly the sale of petroleum. But that is not the only or the most desired source of Iranian finances. Two other sources are intended to be the main ones in the future. One is the export of manufactured goods. Indeed, Iran has been very emphatic in its insistence that industry which is set up in Iran have export potential. The other financial strategy is for NIOC to invest in profit-making oil ventures in other nations. For example, it is a partner of British Petroleum in Exploration of the North Sea for oil deposits. It has a minority interest in small refineries in Madras and in South Africa[143] and is negotiating with Belgian and Greek authorities for the creation of jointly owned refineries in those countries.

Iran has also extensively used long-term loans to finance development projects, so much so that over 4% of foreign exchange payments are now for interest on long-term foreign loans and credit. Foreign assistance has also been drawn upon in industrialization, most of it coming from the nations of the Communist bloc. Nor has the regime been loath to turn to bartering arrangements, the most notable being the repayment of Soviets for the Aryamehr steel mill with natural gas. But neither foreign aid nor bartering appear to be main elements in Iranian financial strategy.

The one goal which is not highly valued by the Iranian regime is the minimization of dependence. That is indicated by the efforts to induce private investment and by the intention to make Iran an exporter, in distinction to making Iran self-sufficient.

Algeria's Goals

Algerian ideology proclaims itself as revolutionary. But Algeria could reasonably be called "The Quiet Revolutionary," for its emphasis under the Boumediene regime has been primarily to pursue internal economic development through massive industrialization. Because of this inward orientation its actions in foreign policy have been relatively unspectacular, its major substantive preoccupation being the forging of a trade policy to complement domestic efforts at industrialization.

The fountainhead of Algerian goals seems to be a desire to achieve certain humanitarian goals related to the income level of Algerian citizens. Mr. Boumediene states that "our national wealth must be exploited at home so that the Algerian citizen may profit from it."[91] A State Department officer in Algeria buttresses this conclusion.

> A leading goal (of the second four year plan) is the elimination of unemployment of 1980 so that each head of family is adequately employed. The government would hope to strongly diminish underemployment and to eliminate unemployment. The second objective would be to raise the income earnings of each family to wipe out malnutrition and to redistribute per capita national income."[92]

The way in which the government means to reach this objective is unmistakably clear. It means to do so through an intensive

program of industrial development. Indeed, all the goals of the regime seem to be centered around the goal of industrialization. Consider Boumediene's assertion concerning agrarian change: "True agricultural development does not precede industry but proceeds from industry."[93] He provides us with a more detailed argument as to why this is so, and at the same time relates extractive sectors to industralization.

> The mineral ore of the Ouenza, for example, must be transformed into steel in our factories, and it is this steel which will enable us to manufacture the tractors necessary for the evolution of our agriculture ... In the same way, the manufacture of large quantities of fertilizer is a prerequisite for the development of the agricultural world and, consequently, for raising the living standard of the Algerian farmer. This necessitates the processing of derivates of petroleum and gas achieved at Arzew and the handling of phosphates from Djebel Onk realized at Annaba.[94]

Analysis of the Algerian budget reveals significant data on the regime's goal structure. The budget is divided into three sections: administrative, investment, and public corporation, the last two constituting the development budget. Table 4 shows the percentage breakdown of the investment and public corporation budgets going to various areas

of government activity. The 46.4% going to industry indicates unquestionably the primacy of industrialization as a national goal. Agricultural development comes in a distant second. Education's rating is deceptively low because most of the funds spent on education are allocated in the administrative budget. In fact, education is on a par with agriculture in terms of total spending.

The structure of the budget, with three concerns getting so much and the other concerns getting relatively so little indicates that the regime has been extremely tough-minded in its pursuit of development. It has focused on meeting needs which it believes to be prerequisites of further development and has been austere with other needs.

A more detailed examination of the Algerian industrialization program is worthwhile. The budget allocation for industry includes money spent on petroleum and mining. A considerable amount of the industrial budget is going to petroleum facilities. Some of the projects under way in the petroleum area are 1) two refineries, one recently completed at Arzew, one tendered for Skidda. This will bring to four the number of Algerian petroleum refineries.[95] 2) Petrochemical complex at Skidda, costing $93 million.[96] This will be the third Algerian petrochemical plant.[97] 3) A methanol and synthetic resin factory at Arzew.[98] In addition, expansion on already existing facilities is underway. Major gas projects include the expansion of the Arzew LNG plant, completion of the Skidda

LNG plant, a new LNG plant at Arzew. In addition two more LNG plants are in the planning stage. Programs have also built pipeline facilities from the gas fields to the LNG plants, and other supplementary programs.[99]

The industrial budget also includes allocations for the mining sector. Although there was some activity in that sector (quadrupling the capacity of El-Abed lead-Zinc mine,[100] increasing extraction from Ouenze mines) it does not appear to have been highly invested in.

The amount spent on industrialization not related to petroleum is still extensive. Major projects include a factory to make electrical equipment (at a cost of $720 million)[101] an auto plant costing $138.78 million,[102] a $73.47 million machine plant,[103] an $80.3 million cement plant,[104] a major expansion of the El Hadjar steel complex at Annabe,[105] and others.

The industrialization program seems to have favored heavy, primary industries and to have slighted smaller industries producing consumer goods.

In the agricultural sector the strategy seems to be fairly mixed. On the one hand, there has been a thrust toward the humanitarian idea of land redistribution. Thus on separate occasions the state distributed its land to peasants and abolished large estates by legally limiting their size and giving excess land to the peasants.[106] On the other hand there has been the impulse towards doing agriculture on a large scale.

Boumedime has stated:

> To carry through the agrarian revolution successfully it is nonetheless indispensable to advance from the traditional methods of cultivation inherited from colonialism and jump right into the era of modern exploitation, having recourse, inter alia, to mechanization and the building of dams.[107]

Thus a considerable amount is being spent on irrigation projects and on the mechanization of agriculture. The way that the regime handles large scale agriculture on small scale units is to "encourage" the establishment of cooperatives run in relatively decentralized fashion by the residents. Expenditures on agrarian reform constitute a package deal. Whole regions are allocated a block sum of money and a cooperative organization is set up simultaneously. The money goes for such obvious needs as equipment, but also goes for drinking water projects, schools, hospitals, houses and new factories. The amount of money allocated to such regional development programs is substantial. For example, $115.2 million was given to the Saida region for its program.[108]

Another aspect of the agrarian program has been its change in crop production. Algeria was faced with a surplus of wine and thus vineyards. Therefore, the government instituted a program of tearing down the vineyards and replacing them with

wheat fields.[109] Also, it set up new factories: one to create surplus wine to cognac, another to convert surplus barley to scotch.[110] In addition, it has spent some money on fishing equipment and fish processing plants.[111]

The massive investment of the regime in heavy industry and agriculture has exactid some severe costs. One is a lack of light consumer-oriented industry. In addition, in order to preserve its foreign exchange reserves and maintain its credit rating the regime was very austere in its import program. Consumer goods were quite scarce, as a result. That was a conscious choice of the regime. Another cost paid was a severe underallocation to the maintenance of some of the infra-structure. Very little was spent on development of transportation facilities, the decision being to depend on the facilities left over from the colonial period. Also, there was not enough spent on housing, so that now there is a minor crisis in that area. Finally, the supply of power facilities has apparently been limited to the heavily industrialized urban areas so that there is that additional discontinuity in the economy.[112]

Algeria has pursued interesting policies in order to resolve the problems created by manpower and financial bottlenecks in the economy. On the manpower front the decision was made to rely on external sources of technical and management expertise in the short-run while depending on education to solve the problem in the long-run.[113]

The decision to rely on external sources for short-run

manpower needs dovetails nicely with financial policy. Essentially, that policy seems to be to get financial help from whatever sources there are, with one caveat considered later. The government borrowed extensively in the world market from both private financial sources and from other governments.[114] It also received extensive help in the form of foreign aid and technical assistance.[115] It imposed a very heavy direct income tax on the citizens, exempting those with small incomes and those who were small landowners (thus helping the goal of income equalization).[116] There was also a value-added tax, which was dropped to a large extent in the 1972 budget.[117] There was an effort to have the public donate money to the agricultural revolution fund.[118] The government also raised money through the export of industrial goods other than crude oil.

In letting contracts for industrial projects the government had as one of its criteria that one company be brought in to take care of the whole job and that it also provide training and initial management services.[119] By adopting this strategy, the regime is able to advance two goals simultaneously. First, it meets manpower needs by guaranteeing short run management and training for the long-run. Second, it helps meet the goal of exercising control over the economy because a project is easier to supervise when it is in the hands of one firm.

Of course, the major source of revenue is the various aspects of the petroleum industry. Algerian actions consistently were intended to increase the amount of revenue generated by

this sector. It nationalized the French oil company Elf-Erap, through a 51% take over. And SONATRACH, the public petroleum corporation, took over 51% of 5 gas treatment plants. But the main ways of increasing petroleum revenues were others. First, there were extensive efforts to increase the amount of petroleum sold. The most obvious were the investments in the LNG plants. There were also some significant efforts in the area of extending upstream facilities: pipelines and pumping stations especially. Another aspect of more sales is new markets. Here Algeria has made extensive efforts, especially in getting new gas customers. A final aspect of increased sales is increased reserves. Algeria has made this an important goal and invested many resources in an extensive but fruitless search for new deposits. A change in strategy saw it inviting help from private companies in the exploration for new deposits, offering guaranteed supplies from what is found.

Algeria also sought to increase petroleum revenues through increased taxes, an action that prompted the conflict that led to the Elf-Erap take over. Since most petroleum activity is through SONATRACH this was a secondary strategy. An increase in the price of petroleum was also a goal of the regime.

Two other areas remain to be discussed. First, the goals of minimizing dependence on external entities, then foreign policy goals. The goal of minimizing dependence has been a significant one for the regime, but probably not the foremost one. Two sets of government actions serve to foster this goal.

One, the government has taken control of various sectors of the economy. This weakens the influence of external sources. Second, the government has produced some economic development, which tends to reduce dependence on imports for fundamental economic needs. However, both these sets of actions were probably motivated by other desires. Economic development was wanted mostly because it would help fulfill the needs of the people. Reduction of imports is necessary for development because it conserves foreign exchange reserves and butresses the credit rating of the country. Government control of enterprises is necessary for development because other wise there will be no guarantee that all due haste will be made in making investments and because government control produces additional revenues for government use.

Algeria appears to have two main foreign policy goals. These are the unification of the Arab Maghreb and the reorientation of its foreign trade patterns. In addition, it has a set of goals to which it gives a verbal allegiance but apparently little more.

The unification of the Arab Maghreb has not been a particularly significant goal in Algerian rhetoric. The main statement of it came in Boumediene's address to the nation in the 10th anniversary of Independence.[120] But a number of actions have been initiated which are conducive to that unification. It has invested $12 million in a project to build a cement factory jointly owned and operated in Morocco, at Oujda.[121] A Moroccan-

Algerian Chamber of Commerce was set up in Algiers.[122] And Algeria and Morocco have agreed to jointly exploit the Gara Djebibet mineral deposits, and to enlist Tunisian help in that project in the future.[123]

Algerian trade policy is motivated by a desire to diversity its trading partners by increasing its trade with its Maghreb neighbors, the third world and with the socialist nations.[124] It also wants to increase its trade with the EEC nations. Stimuli for these desires are two fold. First, trade focused on one country or one region makes one susceptible to being hurt in a conflict. Thus in the Elf-Erap battle France cut off imports of Algerian wine and severely hurt her economy. Second, by increasing her trade in all directions, Algeria will increase its export earnings thereby bolstering her development potential.

In order to alter her trade patterns, Algeria has made two important changes in policy in 1973. It eliminated tarriff preferences given to EEC countries and extended "most favored nation" treatment to all nations except its immediate neighbors with whom it has special trade arrangements.[125] Algeria also gives verbal support to the Arab side in the Arab-Israeli conflict and has given some financial assistance to the PLO. It gives verbal support to the arguments of the poor countries in their efforts to wring more assistance from the developed countries, but it has given only a small amount of aid itself. It has invested very little in foreign policy pursuits, indicated

by a small diplomatic service and a small military force.

1973 is the last year of the present four year plan and although the next plan has not been published yet reports indicate that there may be some significant changes in governmental priorities. These are first a decrease in emphasis on heavy industry.[126] The reason for this change is the meeting of heavy industrial needs in the previous plan periods and the development of other pressing needs. Thus the industrial allocations will shift more to labor intensive small industry, to meet two needs: to soak up unemployment and to meet internal consumption needs better.

Highest priority will appa..tly be given to the improvement of the infrastructure, espec.ally in terms of road construction and railroa. refurbishment. In addition, there will be an increase in the amount of vehicles produced each year. New emphasis will be placed on electrical development.

Agriculture will also be a more favored sector under the new plan, with increased attention to meeting the irrigation needs of the agricultural sector.

Finally, there will be a great emphasis on the housing problems of Algeria, with a major thrust to build 100,000 urban housing units and 120,000 rural family units.[127] This will in turn require the improvement in the status of the construction material industry as a target of government funds.

Thus Algeria's priority structure appears likely to

undergo drastic revision in the near future and deserves a close watching.

Table 4: Percentage breakdown of Algerian investment and planned investment budgets, summed, by area for 1973.

Industry	46.38
Rural development	12.03
Education	6.51
Construction	1.34
Water	4.53
Tourism	1.96
Fishing	.30
Communications	2.52
Telecommunications	.83
Administrative infrastructure	2.08
Rural habitat	1.67
Urban management	.17
Collective equipment	1.67
Social infrastructure	2.18
Social programs	5.42
Transportation	2.97
Urban living	3.75
Industrial zones	1.04
Commerce	.88
Enterprise	1.75
Total in millions of dinars	12.00

FOOTNOTES

1. The Project for Theoretical Politics, supported by ARPA Contract No. DAHC 15 73 C 0197. This paper was written by the author as a summer assistant on the project. My thanks are extended to Dr. Warren Phillips and Dr. Stuart Thorson, the projects principal investigators, for giving the opportunity and assistance to write the paper.

2. A publication of the United States government.

3. Saudi Arabia is excluded from the analysis due to the conservative nature of the regime, as opposed to the professedly revolutionary regimes in the other four nations.

4. FBIS, #75, 18 April 1973.

5. Speech to Majlis presenting the 5 year plan, Kayhan International, 13 January 1973, p.4

6. FBIS, #41, 1 March 1973.

7. FBIS, #116, 16 June 1971.

8. FBIS, #84, 30 April 1971.

9. FBIS, #114, 12 June 1972.

10. FBIS, #143, 24 July 1972.

11. See speech by Kaddafi in FBIS, #114, 12 June 1972.

12. "The Great Fighter", Economist, #245, 23 December 1972, p.26.

13. FBIS, #143, 24 July 1972.

14. Ibid.

15. "One more deadline", Economist, #244, 12 August 1972, p.28.

16. Reported in Arab Report and Record ARR, dated 9 January 1972.

17. FBIS, #114, 12 June 1972.

18. ARR, 30 December 1971; ARR 2 January 1972; ARR, 9 January 1972; ARR, 25 January 1972; ARR, 26 April 1972.

19. ARR, 19 April 1972; ARR, 29 July 1972; ARR, 6 August 1972.

20. FBIS, #114, 12 June 1972.

21. _ARR_, 23 January 1971.

22. _ARR_, 12 October 1971; _ARR_, 11 Novemeber 1971; _ARR_, 18 August 1972.

23. _ARR_, 11 Novemeber 1971.

24. _ARR_, 17 January 1971; _ARR_, 17 August 1971; _ARR_, 2 May 1972; _ARR_, 27 August 1972.

25. _ARR_, 15 June 1972.

26. _FBIS,_ #114, 12 June 1972.

27. _ARR_, 11 August 1972.

28. _ARR_, 7 December 1971.

29. _FBIS_, #143, 24 July 1972.

30. "But whose is the conscience of the nation?", _Economist_ #245, 16 December 1972, pp. 44-45.

31. _ARR_, 6 January 1971.

32. _ARR_, 11 February 1971.

33. _ARR_, 11 September 1971.

34. _ARR_, 14 October 1971.

35. _ARR_, 12 October 1971.

36. _ARR_, 25 October 1971.

37. _ARR_, 8 November 1971.

38. _ARR_, 22 February 1972.

39. _ARR_, 29 May 1972.

40. _ARR_, 24 May 1972.

41. _ARR_, 27 June 1972.

42. Data on which these next claims are based are found in a memo from the American Embassy in Tripoli to the Department of State, Tripoli A-178, November 30, 1972.

43. _ARR_, 29 April 1972.

44. _ARR_, 19 August 1971.

45. _ARR_, 17 January 1971.

46. ARR, 5 December 1972.

47. ARR, 17 Janaury 1972.

48. Tripoli A-178

49. ARR, 13 January 1971; ARR, 26 January 1971; ARR, 3 May 1972 .

50. ARR, 1 September 1971; ARR, 29 October 1971; ARR, 29 February 1972; ARR, 29 June 1972.

51. ARR, 2 January 1971; ARR, 13 January 1971.

52. ARR, 17 September 1971.

53. ARR, 4 February 1972.

54. ARR, 5 January 1972.

55. ARR, 29 October 1971.

56. ARR, 17 January 1971.

57. Memo from the American Embassy in Jidda to the State Department, Jidda A-138 , 19 September 1971.

58. Sources of budget data for Saudi Arabia are: Jidda A-138; Memo from the American Embassy in Jidda to the State Department, Jidda A-90, 16 August 1972; and "Draft Translation: Saudi Arabian State Budget for 1972/1973", 1 August 1973. Conclusions based on Saudi Arabian budget figures must be very tentative because the government consistently spends much less than it budgets, and that holds across all budgetary subdivisions

59. Not all of this expenditure is for entirely military and security purposes, though. For example, according to ARR, dated 15 September 1971, the King Faisal Military City has among its facilities two schools, a hospital, a power station, a water-processing plant and a bakery capable of producing 12 tons of bread per day. Most likely the funds for these were intended to serve some humanitarian goal by having the military base supply the surrounding community in addition to its own internal needs.

60. Saudi Arabian Monetary Agency, Annual Report, 1390-91 A.H. (1971), June 29, 1972, p.41.

61. Ibid, p.56.

62. Ibid, p.46.

63. Ibid, p.48.

64. _Ibid_, p. 94-5

65. _Ibid_, p. 94-5

66. _Ibid_, p. 47-49

67. At Jeddah, Riyadh and Damman, _Ibid_, p. 63

68. These figures have been derived from tables in _Ibid_, pp. 64-65

69. _ARR_, 4 September 1971.

70. _FBIS_. #139, 18 July 1972.

71. _ARR_, 30 January 1971; _ARR_, 24 November 1971; _ARR_, 24 November 1971.

72. Seven tankers were purchased from Spain in November of 1971 at a cost of $28.35 million, and on April 24, 1972 $140.5 million was allocated for the creation of an oil tanker company. See _ARR_, 5 November 1971; _ARR_, 8 January 1972; _ARR_, 24 April 1972.

73. _ARR_, 5 April 1972; _ARR_, 31 August 1972.

74. _ARR_, 29 April 1972.

75. _ARR_, 22 January 1971; _ARR_, 1 February 1972.

76. _ARR_, 14 February 1972.

77. _ARR_, 29 January 1971; in addition to this agricultural program the regime also announced a series of development projects and a road construction program for the Kurdish area, so that there is reason to believe that pacification of the Kurds is a goal unique to the Iraqis and highly salient to them.

78. _ARR_, 28 January 1971.

79. _ARR_, 24 January 1971; _ARR_, 3 January 1972; _ARR_, 20 January 1972; _ARR_, 17 April 1972.

80. _ARR_, 9 January 1971.

81. _ARR_, 10 February 1972; _ARR_, 26 March 1972; _ARR_, 3 September 1972; _ARR_, 4 August 1972.

82. _ARR_, 26 August 1971; _ARR_, 28 January 1971.

83. "Beggars are choosers", _Economist_, #244, 1 July 1972, p. 41.

84. Explicit decisions concerning this involved Soviet agreements to assist in the expansion of production in the North Rumaila fields, ARR, 26 August 1971; ARR, 3 August 1972. A decision was also made to exploit three new fields, ARR, 6 August 1972.

85. ARR, 16 November 1971; ARR 18 December 1971.

86. ARR, 1 February 1972. This action included a demand for the payment of $228 million in back royalties since 1964.

87. ARR, reported 12 instances in which Iraq was a recipient of foreign aid. In 11 of the cases the donor was a member of the communist world. Also, ARR reported 8 cases in which Iraq was the recipient of a long-term low interest loan.

88. ARR, 18 January 1971.

89. ARR, 29 September 1971.

90. ARR, 29 April 1972; ARR, 12 June 1972.

91. FBIS, #67, 7 April 1971.

92. Memo from U.S. Intelligence, Algiers, to the Department of State, "Algeria Prepares for its Third Plan", Algiers A-204, November 1, 1972, p.1.

93. FBIS, # 116, 16 June 1971.

94. FBIS, #67, 7 April 1971.

95. Memo from U.S. Intelligence, Algiers, to the Department of State, "Economic Trends Report", Algiers A-107, 29 June 1973, p.4.

96. ARR, 7 October 1971.

97. Algiers A-107, p.4.

98. Ibid, p.4.

99. Ibid, pp.5-6.

100. ARR, 9 August 1972.

101. ARR, 21 August 1971.

102. ARR, 11 February 1972.

103. ARR, 16, November 1972.

104. ARR, 14 January 1972.

105. ARR, 17 November 1971.

106. ARR, 8 November 1971; ARR, 19 June 1972.

107. FBIS, #167, 7 April 1971.

108. As of October, 1972 8 of Algeria's 13 provinces had been allocated such special assistance, ARR, 5 October 1972.

109. ARR, 26 August 1971; ARR, 10 August 1972.

110. ARR, 23 November 1971.

111. ARR, 30 May 1972.

112. All of the above points were made in Algiers A-204.

113. ARR, 2 February 1971.

114. ARR, reported 23 loans made to Algeria over the period 1971-1972, amounting to a total close to $600 million.

115. ARR, reported 7 grants of foreign aid to Algeria in the period 1971-1972.

116. Memo from U.S. Intelligence, Algiers, to the Department of State, "Algerian Central Government Budget for 1973", Algiers A-009, 10 January 1973, p.1.

117. Ibid, p.1.

118. ARR, 22 April 1972.

119. Algiers, A-107, p.11.

120. FBIS, #131, 6 July 1972.

121. ARR, 12 September 1972.

122. Middle East Journal, 31 July 1972.

123. FBIS, #131, 6 July 1972.

124. Algiers A-107. p.9.

125. Ibid, p. 9-10.

126. Algiers A-204; and Algiers A-107 are sources for predictions of future changes in Algerian priorities.

127. Algiers A-204, p.2

128. For important statements of Uranian perceptions of foreign policy and military problems, see FBIS, #112, 11 June 1973.

129. Information and Press Department, Ministry of Foreign Affairs, Iran To-Day, (Tehran, 1973), p. 50.

130. Ibid, p.61

131. Ibid, p.58

132. Ibid, p.65

133. "The Shah's Turn", Economist, #246, 27 January 1973, pp. 72, 75.

134. Iran To-Day, pp. 101-102.

135. Central Bureau of the Budget, Plan Organization, Report of the Prime Minister on the State of the Iranian Economy, 1347-1350 and Government Programmes for 1351 (Tehran, 1351), pp. 11-13.

136. Iran To-Day, pp. 69-70.

137. Report of the Prime Minister, p. 80.

138. Iran To-Day, p. 45.

139. Report of the Prime Minister, pp 84-86.

140. "While the oil flows", Economist, #246, 3 February 1973, p. 67.

141. Iran To-Day, p. 65.

142. Ibid, p. 73

143. Report of the Prime Minister, p. 17

Oil Module
Working Paper

Robert C. Crain
Project for Theoretical Politics
Ohio State University

December 1973
Project Research Paper No. 15

The research described in this paper was supported by the Advanced Research Projects Agency Contract No. DAHC 15 73 C 0197.

I

Perhaps the most important factor influencing formulation of the oil module is its intended purpose. Clearly, its intent is not (a) to characterize the operation of the world oil industry in any aggregate sense, or (b) to be "valid" for crude oil production in all countries. Neither, however, is it to provide detailed point predictions of the operation of the crude oil industry within any of the nations under study. What we seek is the formulation of a module which represents the characteristics of the oil industry that are considered (by United States policy-planners) to be salient to government officials of the nations under study, subject to the further requirement that the module, when provided with realistic initial conditions and control inputs, behave plausibly in the view of knowledgeable observers. This last point should be commented upon further.

In the decision module, producing-nation decision-makers will observe and measure the performance of various sectors (processes) through the use of monitor variables.[1] Monitor variables are just what their name would lead one to expect: a small set of information variables which tap the key characteristics of a process and which are of interest for decision-making concerning that or another process. They may come directly from a process, or they may result from analysis of and abstraction from the data produced by the process. In our oil module, then, we want to explicitly include any variables

directly involved in the process which are also likely to be used unaltered as monitor variables. We also wish to include any variables directly involved in the process which are likely to be analyzed or abstracted from in order to obtain values for monitor variables. In this latter case, however, we may not be aware of the need to include some process variable until we encounter that need during development of the decision module, and so we wish to emphasize especially that no claim is made that all necessary process variables have been included in our initial version of the oil module.

Similarly, we ideally would like to have no more detail in the process module than is necessary to provide reasonably accurate values for the monitor variables. If one recalls that the purpose of the module is only to permit analysis of decision-maker choices, then detail beyond that necessary to generate the monitor variables becomes relatively superfluous.

We would also like to obtain some sort of consensus of knowledgeable observers, concerning the monitor variables (and, if necessary, how they are generated), before the structure of the oil module is finally determined. This can be accomplished through an iterative process. Our initial version of the oil module will be considered by knowledgeable policy-planners and they will respond with criticism and suggestions. On the basis of such feedback, revisions to the module will be made, then additional feedback will be sought, and so on until some minimally acceptable degree of consensus is reached concerning the suitability of the module. It is not anticipated that

this process will take long for the module considered by itself. During development of the decision module, however, it may become necessary to add complexity to the module if unanticipated monitor variables are introduced.

The intended purpose of the module has had another effect upon the module's development. Although there is a large literature on oil and oil economics, relatively little of that literature seems to deal in detail with oil operations from the viewpoint of the producing-nation decision-maker. This is probably quite reasonable given the relative lack, until recently, of detailed intervention into the oil industry by the producing-country governments. Nonetheless, it precludes the possibility of using or modifying a previously developed model. This is a somewhat more severe drawback with respect to the oil module than it would be in other sectors, since oil companies are notably non-communicative with respect to information on decision-making aspects of their operations, and the producing-country governments also are understandably reluctant to explicitly reveal their decision criteria and/or monitor variables.[2]

The initial formulation of the oil module contains, as a result, a number of important assumptions. These assumptions will be identified in the next section when the module is described. We hope that most of the assumptions represent reasonable inferences from some of the oil and oil economics literature, given our particular goals for the module.

In addition, the relationships of the producing-country

governments to the operations of the oil industry within their boundaries have been changing rapidly, especially in the last year. The governments have asserted increasing control over contractual arrangements with the oil companies, and over crude oil prices. Initially it was our intention to include contractual arrangements and the Teheran pricing agreement within the module, and to treat them as relatively stable for at least the next few years. Given the turmoil in country-company relationships during especially the past nine to twelve months,[3] however, it seems advisable to consider all contractual arrangements and posted price schedules as scenarios which should be explicitly specified by the user.[4] That is, the emphasis has shifted so that rather than try to consider country-company relationships relatively constant or attempt to generate crude oil prices <u>within</u> the oil module, we simply intend to consider both these areas as exogenous to the process module and currently, at least, as unpredictable beyond the accuracy of a sophisticated observer's educated guess. Eventually it should be possible to include within the decision-module the effects on crude oil prices of producing-country governments.

A final aspect of our module's context which has influenced the module itself is the peculiar nature of crude oil operations in the Middle East, in the Persian Gulf, and in North Africa. In these areas oil lies in huge more or less contiguous pools. The pools are under high natural pressure; water and gas generally are injected into the fields to replace the oil

removed and maintain the pressure, but negligible pumping of oil at the wellhead is necessary, and daily production per well is extremely high. In addition, the legal systems of these countries vest title to, and thus control of, mineral resources in the state. Thus the oil industry has been able to develop these large pools in optimal fashion, drilling only the necessary numbers of wells for the desired rate of production, and drilling them in optimal locations. The result of all of these factors is a very low cost of production, and relatively little uncertainty affecting decisions regarding how to raise production capacity. These implications will be discussed in more detail in the next section, but their general impact on the module is that we may deal with the process aspects of each nation's crude oil operations in relatively highly aggregated form because those operations are quite homogeneous compared with the character of operations in other parts of the world.

Footnotes for Section I

[1]See (especially Chapter 4 of) H.H. Bossel and Barry B. Hughes, Simulation of Value-Controlled Decision-Making: Approach and Prototype, mimeo, 1973.

[2]Except, perhaps, for their demonstrated concern for the posted price of crude oil and for producing-country revenues from oil exports.

[3]For instance, an article in Oil and Gas Journal, (December 31,1973, p. 55) suggests that even the most recently announced posted prices may only be valid through April, 1974.

[4]A small number of "standard" scenarios will be available, and a user may select one of these for his run. But these "standard" scenarios should nonetheless be regarded as speculative.

In keeping with the discussion in the previous section, it should be remembered that the module about to be presented is an initial working version. It provides the basis for discussion with, and critical feedback from, knowledgeable decision-makers. We fully anticipate that some revision will be necessary, and indeed have made ease of revision a key feature of our computer programming.[1]

On the other hand, the oil module does represent our efforts at gaining at least a working understanding of the fundamentals of crude oil operations in the producing countries, and also our attempts to simplify, as much as possible, our representation of those operations through the use of what we feel are plausible assumptions and inferences from the literature on oil economics. More will be said later concerning these assumptions, their effects, and our grounds for employing them. First, however, the operation of the module itself will be described. When reading the following description, it will be useful to refer to several figures and a table. Figure II-1 is a simple flowchart of the computer program for the oil module, and Figure II-2 gives the actual current program (written in PL/I). Table II-1 lists all variables employed in the module, along with their definitions and units. Finally, Figure II-3b indicates the conceptual organization of the module.

FIGURE II-1

Simple Flowchart of Computer Program

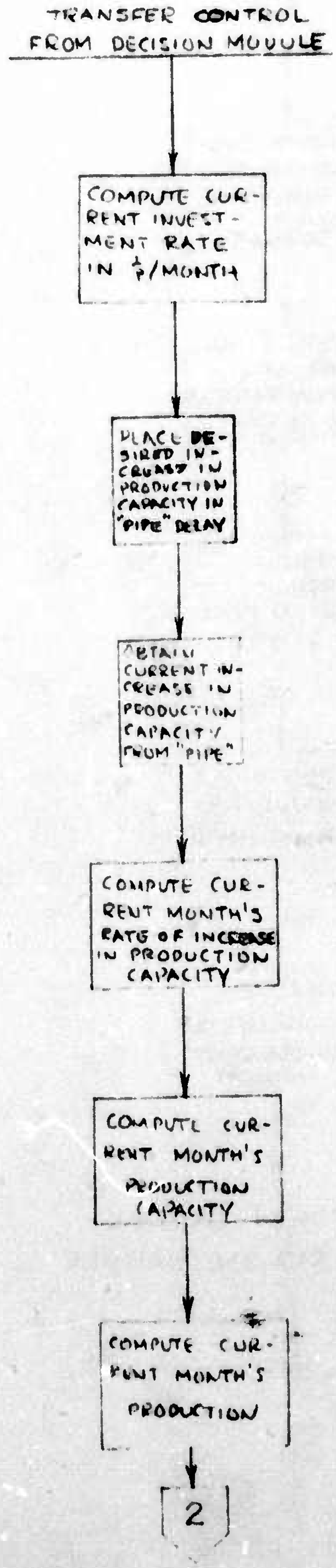


FIGURE II-1 (cont.)

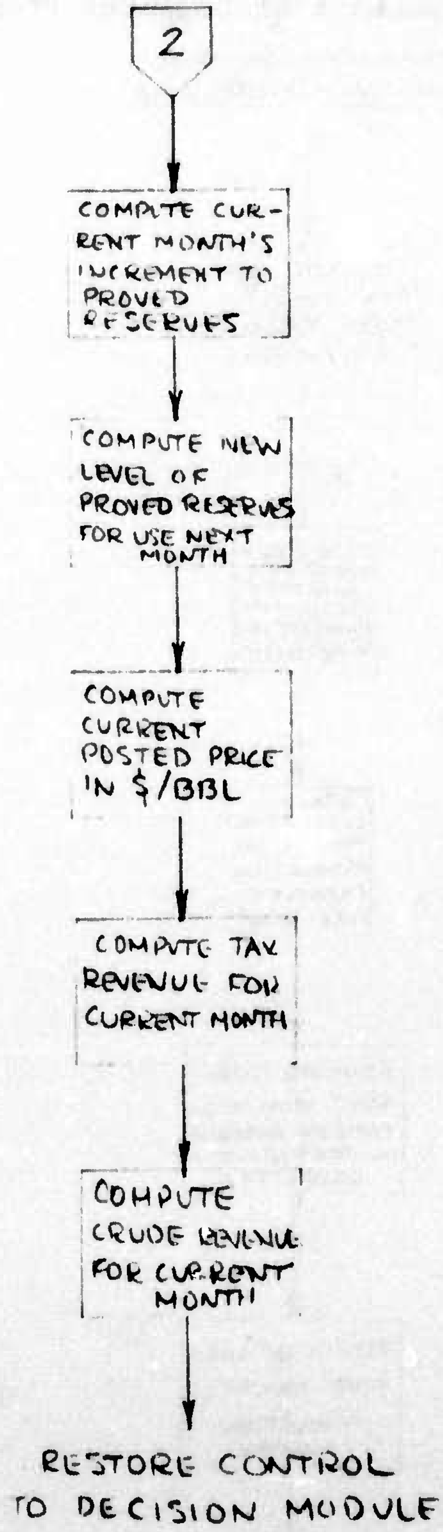


Figure II-2

Listing of Current Program for Oil Module:

```
OIL: PROCEDURE;
  %INCLUDE ADBR;
  %INCLUDE COCI;
  %INCLUDE COP;
  %INCLUDE DAYS;
  %INCLUDE DPIR;
  %INCLUDE DR;
  %INCLUDE EI;
  %INCLUDE IR;
  %INCLUDE MP;
  %INCLUDE P;
  %INCLUDE PAPC;
  %INCLUDE PC;
  %INCLUDE PINCRAT;
  %INCLUDE PR;
  %INCLUDE PRR;
  %INCLUDE CF;
  %INCLUDE CR;
  %INCLUDE CRUDE%;
  %INCLUDE IND%;
  %INCLUDE INDCRUD;
  %INCLUDE INDSALE;
  %INCLUDE PP;
  %INCLUDE ROYALTY;
  %INCLUDE SELBAC;
  %INCLUDE SELBACP;
  %INCLUDE SHARE;
  %INCLUDE TAXPAID;
  %INCLUDE TAXRATE;
  %INCLUDE THISCUR;
  %INCLUDE TPOST;
  %INCLUDE TR;
```

```
%INCLUDE YEAR;

/* compute current investment rate in $/month */
        IR=DPIR*COCI;
/* place desired increase in production capacity
   into "pipe" delay */
        CALL INPIPE('EI', DPIR, ADBR);
/* obtain current increase in production capacity
   from "pipe" delay */
        EI=OUTPIPE('EI', EIPARM);
/* compute current month's rate of increase in production
   capacity */
        PINCRAT=EI/PC;
/* compute current month's production capacity */
        PC=PC+EI;
/* compute current month's production */
        P=PAPC*PC;
        MP=DAYS*P;
/* compute current month's gross increase in proved
   reserves */
        DR=PRR*PR*PINCRAT;
/* compute new level of proved reserves for use
   next month */
        PR=PR+DR-MP;
/* compute current posted price in $/bbl */
        TESTCUR=(THISCUR-LASTCUR)/LASTCUR;
        IF TESTCUR≥.Ø1 THEN CF=TESTCUR;
            ELSE CF=Ø;
        LASTCUR=THISCUR;
        IF YEAR=74 THEN IF MONTH=1 THEN SWITCH=1;
            ELSE IF YEAR=75 THEN IF MONTH=1 THEN SWITCH=1;
            ELSE SWITCH=Ø;
        TPOST=TPOST+SWITCH*(.Ø25*TPOST+.Ø5);
        PP=PP+TPOST*CF;
/* compute tax revenue for current month */
        TAXPAID=(PP-COP-ROYALTY*PP)*TAXRATE+ROYALTY*PP;
        TR=TAXPAID*MP*(1-SHARE);
```

```
/* compute independent crude revenue for current month */
        INDCRUD=CRUDE%*MP;
        SELBACP=Ø.5*(TAXPAID+PP);
        SELBAC=SELBACP*(SHARE*MP-INDCRUD);
        INDSALE=INCRUD*(IND%*PP-COP);
        CR=INDSALE+SELBAC;
END OIL;
```

Listing of INPIPE and OUTPIPE procedures, which collectively comprise the "pipe" delay:

```
INPIPE:  PROC(PIPE, VALUE, IDELAY);
         DCL 1 PIPE,
             2 MAX B F(31,Ø),
             2 CELL (*) B FLOAT;
         DCL VALUE B FLOAT;
         DCL IDELAY B F(31,Ø);
         IF MAX<1|MAX>100|IDELAY<Ø THEN DO;
             PUT 'FATAL INPIPE CALL'
             SIGNAL ERROR; END;
         IF IDELAY>MAX THEN DO;
             PUT 'INPIPE MAX USED'
             IDELAY=MAX;
             END;
         CELL(IDELAY+1)=CELL(IDELAY+1)+VALUE;
         END INPIPE;

OUTPIPE:  PROC(PIPE,IPARM);
         DCL 1 PIPE,
             2 MAX B F(31,Ø),
             2 CELL (*) B FLOAT;
         DCL IPARM B F(31,Ø);
         IF MAX<1|MAX>100 THEN DO;
             PUT 'FATAL OUTPIPE CALL'
             SIGNAL ERROR; END;
```

```
TEMP=CELL(1);
IF IPARM=1 THEN DO I=2 TO MAX ;
    CELL(I-1)=CELL(I);
    END;
    CELL(MAX)=Ø.Ø;
    END;
RETURN (TEMP);
END OUTPIPE;
```

Table II-1

Oil Module Variable List

I. Variables in physical process section of module

ADBR	months	Average Delay Before Return: typical number of months before a given amount of capital invested in production facilities actually increases production.
COCI	$/bbl/da	Cost of Capacity Increase: average overall cost of an increase of 1 bbl/da in production capacity.
COP	$/bbl	Cost of Production: average cost of producing 1 bbl of crude oi' and delivering it to a tanker loading facility.
DAYS	days	Days: number of days in the current month.
DPIR	bbl/da	Desired Production Increase Rate: the number of bbl/da production capacity is desired to be increased ADBR months later.
DR	bbl	Discovery Rate: gross increase to proven reserves for a given month.
EI	bbl/da	Effective Investment: the increase in production capacity which is to become operational during the current month.
IR	$	Investment Rate: the amount of capital to be invested in order to achieve an increase in production capacity ADBR months later.
MP	bbl	Monthly Production: actual production for the current month.
P	bbl/da	Production rate: average actual production per day during the current month.

PAPC	dimensionless	Production As Percent of Capacity: the level of production desired by government decision-makers expressed as a fraction of present capacity.
PC	bbl/da	Production Capacity: average daily production capacity for current month.
PINCRAT	dimensionless	Percentage Increase in production capacity: ratio of increase in production capacity to production capacity before increase.
PR	bbl	Proved Reserves: current estimate of oil-in-place which can be recovered with existing facilities and technology and at current prices.
PRR	dimensionless	Proved Reserves Ratio: assumed constant factor which indicates how large an increase in proved reserves will be associated with a given percentage increase in production capacity.

II. Variables associated with contractual arrangements section of module

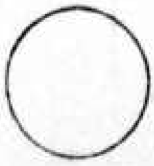
CF	dimensionless	Currency Factor: index of the rate of inflation or deflation of a designated group of currencies.
CR	$	Crude Revenue: revenue accruing to a producing country government through sales of crude oil it owns as a result of participation contracts.
CRUDE%	dimensionless	ratio of that portion of the current month's production which is owned by the producing country government, and which is to be sold independently by the government, to the current month's production.

IND%	dimensionless	ratio of the price at which independent sales of crude oil are made (by a producing country government) to the posted price.
INDCRUD	bbl	the amount of the current month's production which will be sold independently by the producing country government.
INDSALE	$	revenue received by the producing country government from its independent sales of crude oil.
PP	$/bbl	Posted Price: the artificial price used in country-company relationships as a basis for determining (for tax purposes only) company "profits".
ROYALTY	dimensionless	the fixed proportion of posted price which is paid, on each company-owned barrel, as a royalty to the producing country government.
SELBAC	$	revenue received by the producing country government as a result of sales of its share of crude oil production by the oil companies through their regular channels. Such oil is said to be "sold back" by the countries to the companies.
SELBACP	$/bbl	Sellback Price: the price at which sellback transactions are made by the producing country government.
SHARE	dimensionless	the ownership share (proportion) of the producing country government under the terms of a participation agreement.
TAXPAID	$/bbl	Tax Paid price: the cost to oil companies for their share of the oil produced.

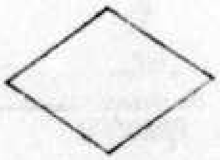
TAXRATE	dimensionless	the proportion of company "profit" on each barrel of crude oil which is owed to the producing country government as a tax.
THISCUR	$	the average value, in $, of a designated group of currencies for the current month.
TPOST	$	posted price which would apply at a given date under the terms of the 1971 Teheran agreement, but excluding the effects of the 1972 and 1973 Geneva agreements.
TR	$	Tax Revenue: the sum of all taxes and royalties paid to the producing country government for the current month's production.
YEAR	yr	the current year at any time during a simulation run.

FIGURE II-3a

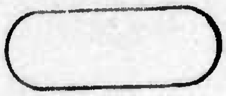
Legend for symbols used in Figure III-3b:



Process information variable

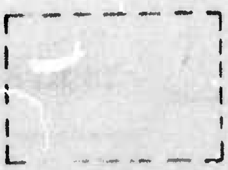


Control information from control stratum



Exogenous information provided by user

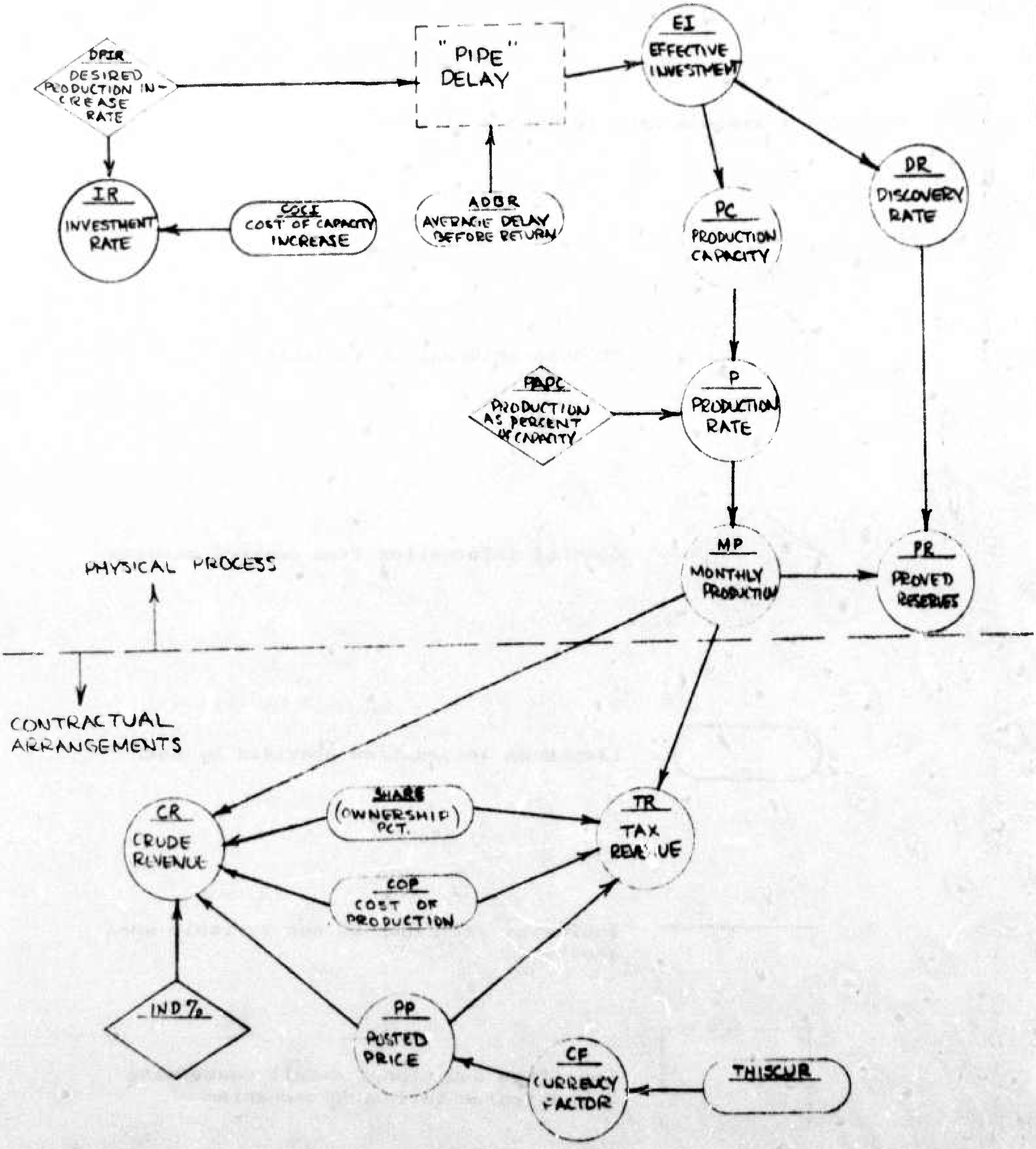
Indicates influence of one variable upon another



Specifies additional detail concerning a particular influence mechanism

FIGURE II-3b

Conceptual Flowchart of Module



Best
Available
Copy

Table II-2

Some Initial Values and Estimates for Saudi Arabia*

SHARE	1973	.25
	74	.25
	75	.25
	76	.25
	77	.25
	78	.30
	79	.35
	1980	.40
	81	.45
	82	.51
	after 1982	.51
ROYALTY	.125	
TAXRATE	.55	
COP	$ .10/bbl at present; increasing to $ .20/bbl in 1985. Assume linear increase. (From Adelman, 1972)	
COCI	$ 313/bbl (Taken from Aramco investment program; Assume $ 500 million annually for avg. production increase of 1.6 million bbl/da.)	
PAPC	1.0 initially, but subject to reduction by decision module.	
TPOST	$ 2.18 initially; adjusted by module thereafter.	
PR	92,992 million bbl (Aramco Annual Report 1972) This figure is low for Saudi Arabia as a whole, but all Aramco figures are used here so that data inconsistencies are minimized in this example.	
DDR	.1772 computed for increases in PR and P for Aramco in 1972.	
P	5,733,000 bbl/da (Aramco Annual Report 1972)	

*The values given here are meant to be mainly illustrative. Detailed values and estimates will be given when module is test-run and evaluated.

The module begins each month with a known level of proved reserves (PR), and with a given level of production capacity (PC). If the decision module has determined that an increase in production capacity is necessary and/or desirable, then a desired production capacity increase rate (DPIR) will also be known when the oil module begins operation. When the desired production capacity increase rate (DPIR) is nonzero, some level of capital investment in additional production facilities is called for. In that case, the module relies upon an exogenously supplied cost of capacity increase (COCI) factor, and determines the necessary capital outlay (IR). The desired production capacity increase is then placed into a "pipeline" type delay mechanism.[2]

The module next checks to see if any new production facilities, resulting from earlier decisions to increase production capacity, are due to come on line during the current month. If so, production capacity (PC) is increased by the appropriate amount (EI). Under "normal" circumstances, it is assumed that production will be maintained at essentially 100% of capacity. However, the decision module may have provided that production take place at something less than 100% of capacity. In either case, the production rate (P) for the current month is determined from the product of production capacity (PC) and production as percent of capacity (PAPC). The production rate (P) is expressed

in barrels per day (bbl/d), and the cumulative monthly production (MP) is determined by multiplying P by the number of days in the current month. Cumulative monthly production (MP) is then subtracted from proved reserves (PR). If any increase in production capacity (PC) has taken place, however, an increase (DR) is also made to proved reserves (PR). The magnitude of such an increment to proved reserves is determined by the percentage increase in production capacity (PINCRAT) which came on line during the current month.

At this point, the (very highly aggregated) representation of "physical" crude oil operations is complete. It was suggested in the prior section, however, that the oil process module should take into account whatever variables are required in order to produce the variables monitored by the decision module. Since we assume that oil revenues are important to the producing-country decision-makers, we also include the country-company contractual arrangements in our module. These are currently in a state of flux, and so as a specific example for this working paper we show the contractual arrangements which would have been in effect for Saudi Arabia had the 1971 Teheran agreement, the 1972 and 1973 Geneva agreements, and the 1972 participation agreement not been superceded.[3]

Under those arrangements, our module would first determine the current month's posted price (PP) in dollars per barrel in accordance with the provisions of the above

mentioned agreements. The terms of those agreements provided for monitoring an index based upon a group of currencies and adjusting the posted price (to compensate for inflation) whenever the index changed value by more than 1% from its value for the previous month; the value of the index would be specified by the user for the time period to be simulated.

After the value for posted price (PP) has been determined, the tax revenues (TR) to be paid to the producing country would be computed using the current TAXRATE, ROYALTY, cost of production (COP), and the government's current participation SHARE. Similarly, the revenue accruing to the producing country government as a result of sales of its independently owned crude oil is computed. The crude revenue (CR) is determined from consideration of the amount of crude oil sold independently by the government (INDCRUD), the price received by the government in such transactions (INDSALE), the cost of production (COP), and the price (SELBAC) paid to the governments by the companies for country-owned crude "bought back" by the companies. After completion of computation for crude revenue and tax revenue, control passes back to the decision module.

The producing government decision-makers are considered here to evaluate the performance of the oil sector at the end of every month, and then to make whatever adjustments they consider appropriate for the next month's operations. These adjustments (if any) are embodied in the values of

various parameters (i.e., DPIR, PAPC) which are provided when the oil module is activated each time by the decision module.

However, although the logical organization of the oil module is very simple, a few of the individual operations within it, which are claimed to be reasonably suitable representations (for our purposes) of crude oil operations, should probably be discussed in more detail. In particular, the existence of several assumptions should be made explicit, and arguments for their use should be presented. As mentioned earlier, the assumptions made reflect (hopefully) the unique character of crude oil operations in the countries of interest, and should be interpreted only within this limited context.

There are two parts of the module which should be discussed. The first is that dealing with capital investment and increases in production capacity. In the present version of our module, governmental decision-makers in the producing countries are assumed to formulate a desired production level to be reached at a given target date. If the currently available production capacity is insufficient to permit production at the desired level, it is assumed that the decision-makers will build (or permit to be built) the necessary additional capacity. The decision-makers will produce a scheme which specifies the additional capacity per month (DPIR) which is to be added over some chosen number of months ending with the target date. If the

currently available production capacity is more than sufficient to permit production at the desired level, then the decision-makers will decide to produce at less than 100% of capacity. In this latter case, the parameter PAPC will be set to the appropriate value (less than 1.0) whenever the reduced production level is to go into effect, and then will be adjusted in succeeding months to further decrease, to increase, or to maintain the same level of production.

The major assumption taken when the module was formulated was that (within reasonable limits) there is no opposition by the major oil companies to increasing production capacity, and that in fact they will always push to increase production (and thus production capacity) to the maximum level permitted by the producing-country government.[4] This further assumes that nothing restricts the companies or countries' ability to afford whatever level of capital investment is necessary for such capacity increases. In Saudi Arabia, at least, these two assumptions seem reasonable. Aramco, the major oil producing company in Saudi Arabia, has undertaken a major expansion program aimed at increasing production there from 9 million bbl/da at the end of 1973 to 20 million bbl/da at the end of 1980, and the program was undertaken even though Saudi opposition to production rates greater than 7-8 million bbl/da was publicly known.[5] Furthermore, during the embargo the Saudi government showed itself quite capable of reducing production to less than 100% of capacity, at least in the short run.

Finally, we assume that producing country decision-makers are aware of the value of ADBR, the average delay between the time capital is committed for an increase in capacity and the time such new capacity is fully installed and operational. Given that all of the countries of interest here have experienced sizeable increases in production levels during the last decade or so, it seems reasonable that they would have reasonably accurate data on how long it takes to construct and connect various kinds of new facilities (including wells). An implicit assumption here, however, is that relatively little uncertainty attends decisions concerning how production capacity can be increased (where to drill, and so on). In the countries under study, and especially in the Persian Gulf, this is a very reasonable assumption. Known reserves and pools are capable of supporting relatively large increases in production with the application of straightforward development processes.

The second part of the module which should be discussed is that concerning increases to proved reserves. Proved reserves are the amount of oil ultimately recoverable with presently installed equipment and under current economic conditions. They may represent either a relatively large percentage or a relatively small percentage of the oil-in-place in a given pool or field, depending upon conditions within the pool or field and upon how extensively developed the pool or field may be. But it is important not to confuse proved reserves with

oil-in-place, since the former are influenced by both economic and operational considerations, while the latter is not. Adelman points out that "The more development wells are drilled into a pool, the more is known about the character of the pool and the better become the estimates of what will probably be produced from it."[6] Furthermore, "The oil company can thus keep on adding to its proved reserves for many a year without ever finding a new field or even a new pool, and with zero or modest additions to oil-in-place."[7]

The oil module takes account of increases to proved reserves which result from development drilling, but makes no attempt to account for any increases which might result from discovery of major new fields. There are two major reasons for this. First, even if a major new pool or new field were to be found, its initial impact would probably be much greater upon estimates of oil-in-place than upon estimates of proved reserves. One cannot say a great deal about ultimate recoverability (with reasonable confidence) until one attempts to define the limits of the pool or field and has performance data from wells drilled for that purpose. But in the Middle East, at least, any pool or field which would add significantly to proved reserves would, because of geological conditions in that area, also be likely to produce huge amounts from these developmental wells. Hence an addition to proved reserves

would once again tend to be associated more closely with a notable increase in production than with the initial "wildcat" well.

The second reason for ignoring the wildcatting type of exploration has been stated very clearly by H.R. Warman: "It is my firm belief that the heyday of discoveries in the Middle East is past and although many large fields (by world standards) remain to be found there the bulk of the oil and the largest fields have been found."[8] And, from Adelman again, "Let us refrain from guessing what this continued [Eastern Hemisphere exploration] activity means for finding new fields. The effect of chance is too great."[9] It thus seems reasonable to permit the user to exogenously raise the level of proved reserves to simulate the chance discovery of a major new field, but it seems equally reasonable not to attempt to treat wildcat exploration within the module.

The next step in development of the oil module is to conduct a series of trial runs using data from various countries of interest. This will be done as soon as the overhead programming general to all the modules is completed. At that time, the performance of the module in its present form may be more fully appraised, and any necessary modifications made and tested. In addition, more detailed documentation will be produced on the various parameter values calculated and parameter estimation

methods used. In the meantime, this working paper should serve as an introduction to the structure and logic of the basic module, and as an indication of the direction of the module's development.

Footnotes for Section II

[1]The ease of revision is built into the overhead programming for the simulation, and thus is not seen in the source code for the oil module shown in Figure II-2.

[2]This delay mechanism is a very simple one. The desired production capacity increase is stored for a given number of months, where the number of months is meant to be an approximation of the time required for the needed facilities to be built and to become operational. After the given number of months has passed, the capacity increase is brought "on line" and considered fully operational.

[3]For details of the Teheran and Geneva agreements, see respectively:
OPEC Annual Review and Record, 1971, pp. 7-8.
Petroleum Press Service, July, 1973, pp. 263-64.
For details of the Saudi participation agreement, see "Boom Times in the Gulf," Washington Post, July 22,1973, pp. C2-C3.

[4]This is for the case where capital investment for capacity increases is the responsibility of the contracting oil companies. If the responsibility for capital investment lies with a producing country's national oil company, there would seem to be no problem, subject of course to the national oil company's ability to raise the necessary capital.

[5]"Boom Times in the Gulf," Washington Post, July 22,1973, pp. C2-C3. See also the New York Times, August 9, 1973, for details of the Aramco investment program.

[6]M.A. Adelman, The World Petroleum Market, Baltimore: Johns Hopkins University Press, 1972, p. 28.

[7]M.A. Adelman, 1972, p. 30.

[8]H.R. Warman, "The Future Availability of Oil," paper presented at the Financial Times/BOAC Conference on World Energy Supplies, 18-20 September, 1973, Grosvenor House, London, p. 8.

[9]M.A. Adelman, 1972, p. 205.

Agricultural Sector Module:
A Preliminary Sketch

Michael K. Hainline
Project for Theoretical Politics
Ohio State University

December 1973
Project Research Paper No. 16

The research described in this paper was supported by the Advanced Research Projects Agency Contract No. DAHC 15 73 C 0197.

INTRODUCTION

Oil clearly has been a dominant factor in the economies of these Middle Eastern countries. But to focus solely on the oil sector is to present an incomplete picture of Iran, Iraq, Saudi Arabia, Libya, and Algeria. While this sector constitutes the major source of revenue for each country, it remains only one of several important sectors "defining" the environment within which decision-makers in these countries operate. Another important sector in this setting is the agricultural sector.

After oil production, agriculture is the largest single contribution to the national accounts (i.e., the national income, the GNP, the balance-of-payments, etc.) of each of the five countries. The agricultural sector, moreover, is the principal source of employment in these oil-producing countries, with more than half of the population in each country (except Libya) deriving its livelihood from agriculture. Due to a number of constraints (e.g. limited water resources), however, the level of agricultural productivity in these countries are not able to produce enough on their own to meet the ever-increasing food needs of their respective populations. Further, with ever-growing populations and rising demands for better standards of living, they face the strong possibility of widespread famines breaking out in the not-too-distant future. To avert this situation, extensive efforts are being made in each country to modernize and dev-

lop, the agricultural sector.

It is in the context of these development efforts that we have attempted to construct a simulation model of the agricultural sector in these five countries. Specifically, we have sought to formulate a structure which would enable us to (1) identify and trace the various information and material flows in the agricultural production process which influence the decision-makers' choices of developmental policies and programs, and (2) project the consequences that their choices might have for the output behavior of the agricultural sector. To this end, we have adopted a "building-block" approach to modeling this sector. The complex array of variables and interrelationships are conceptually grouped into several sequentially-linked "logical components", or building-blocks, to simulate various facets of the production process. Four such components are included in the present version of the agricultural simulations: resource allocation, modernization, production/marketing, and consumption/demand components. The output of a component is either an input to another component or a performance variable, or both. The final outputs of the model thus included not only physical outputs, but also a set of performance variables. It is this set of variables which the decision makers evaluate and compare with policy goals when choosing their policies and programs for the next time period.

At present then, we have a model which is structures to simulate the production of field crops (specifically wheat,

simulate the production of field crops (specifically wheat, the principal crop and food staple) in these oil-producing countries. Parameter values are available for one country (Saudi Arabia) and will soon be ready for the other four.

THE SETTING: Herausforderung und Antwort

Oil clearly has been a dominant factor in the economies of these Middle Eastern countries. Yet, to focus entirely on the oil sector is to view a rather distorted picture of these five countries. For despite the tremendous wealth derived from oil production, there has been little appreciable change, if any at all, in their overall economies. Put somewhat differently, inspite of their vast capital surpluses, these countries are still economically underdeveloped. But there, the overall economic development of these countries depends upon more than the accumulation of capital surpluses, upon more than the growth in the productivity of this one sector. It also depends, to a considerable extent, upon the modernization and development of the agricultural sector.

Agriculture constitutes a major sector of both the economy and the social structure of each of the five countries examined here. After oil production, it is the largest single contributor to the national accounts (i.e., the national income, the GNP, the balance of payments, etc.) of these countries. And, whereas the oil sector represents the major source of revenue for these countries, the agricultural sector is the principal source of employment and individual income. More than half of the population of four of these countries (Algeria, Iran, Iraq and Saudi Arabia) derive their livelihoods directly from agriculture. In Libya's case this figure is considerably smaller (approximately one-third of the population), yet it still represents the largest share of the population involved

in any one sector of the Libyan economy.

Despite the rather sizable input of labor to the agricultural sector, agricultural productivity in these Middle Eastern countries is not very high. Winter grains such as wheat and barley (the principal grain crops of these countries), for example, rarely produce yields above fifteen bushels per acre per year, even in relatively good years.[1] At such levels of productivity, these countries are barely able, if at all, to produce enough on their own to meet the present food needs of their respective populations. All-too-often, in fact, they must import large quantities of food to "fill up" their frequently-deficient food accounts. And confronted with ever-growing populations and rising demands for better standards of living, these countries are likely to become even more dependent upon external sources of food. For unless agricultural productivity can be significantly raised above present levels (or otherwise augmented), these countries face the possibility of widespread famines breaking out in the not-too-distant future.

Considerable efforts are thus being made in these countries to increase agricultural productivity, to modernize and develop the agricultural sector. If these efforts are to succeed, however, a number of rather formidable obstacles must be overcome. One major obstacle which has long limited agricultural production in these countries is their relative lack of adequate water supplies. For the most part, these countries depend upon rainfall to provide the water needed for crop production. But

because of the arid nature of the climate in these countries, the rainfall they receive is both low and highly variable over time. Many areas of these countries, in fact, receive so little rain as to make the production of rain-fed crops well-nigh impossible. As a result, the amount of cultivable land in each country is limited to a rather small percentage of each's total land area. (See Table 1) And where this land is actually put under cultivation, the utilization of this land for rain-fed crops (which the major share of the crops grown in these countries are) requires the adoption of such practices as placing the cropped area in fallow during alternate growing seasons. Under such conditions, it is hardly surprising that these countries have thus far been unable to realize their full agricultural potential.

The alternative to this dependence upon rainfall for crop production is, of course, the extension of irrigation to the areas to be cultivated, both present and potential. But to bring these areas under irrigation requires that these countries have alternative sources of water in sufficient amounts to meet the water requirements of the area (and crop) to be irrigated. Of these five countries, however, only Iraq appears to be well-endowed with such a supply of irrigation water. With a combined average annual flow of around 61 million acre-feet, the Tigris and Euphrates rivers clearly provide Iraq with a great potential for irrigation.[2] Using only part of this supply (approximately 28.4 million acre-feet), the Iraqis have

Table 1. Land Utilization in the Five Countries
(in 1000 acres)

	Algeria	Iran	Iraq	Libya	Saudi Arabia
Total Land Area	688,800	164,800	110,900	117,500	550,000
Cultivable Land	6,700	22,000	16,700	17,500	82,500
Cultivated acreage	3,700	7,000	8,100	1,175	600
Area irrigated	99	3,000	4,600	555	n.a.

been able to put an estimated 7.5 million acres of crop land under irrigation thus far.[3] As to the other four countries, they do not possess any readily-accessible supplies of irrigation water which are comparable to those in Iraq. Iran also depends upon the Eurhrates River for irrigation water, but the amount of water it is able to extract from this source is definitely not sufficient to meet Iran's present and projected water needs. The situation is even bleaker for Algeria, Libya and Saudi Arabia; there are no rivers, lakes, etc., of any practical significance in these countries.

From where, then, can these countries get the water they need? One source is to be found underground, i.e., groundwater from wells. Information on how extensive the supply of this water is, however, is rather scanty. A more certain source of potential irrigation water is, of course, seawater. In both cases, the production costs involved in tapping these sources are substantial. The cost of producing ground water, for example, presently runs about $130 per acre-foot.[4] In contrast, the cost of desalination, given existing technology, is about one dollar per 1000 gallons, or about $326 per acre-foot.[5] As these countries have to dig deeper wells, and as desalinization technology advances, the difference in the costs of these two alternative sources is likely to diminish.[6] But for the present time, and for the forseeable future, it is the production of groundwater which, in terms of cost, provides the more practical solution to the water problem in these

countries.

Whatever the source, it is abundantly clear that the development of irrigation water constitutes an essential ingredient in any effort to increase the agricultural productivity of these countries. Water by itself, however, is not the only prerequisite for increased agricultural production: "Indeed, neither water nor any other single input is the magic wand that will quickly and painlessly produce agricultural plenty and prosperity."[7] Thus, if the extension of irrigation to the cultivated areas is to be of any lasting benefit, it must be accompanied by a number of additional, but equally important production inputs. These additional inputs are essential, for the scarcity of water does not constitute the only obstacle to the expansion of agricultural production.

A second major obstacle to increased agricultural production is the general lack of soils suitable for cultivation. Suitable soils are as scarce in these countries as water, if not more so. As a result, only a small fraction of the land in each country is truly cultivable. Even in those areas where cultivation is possible, the suitability of the soil is limited. There are two aspects of the soils in these countries which in particular pose major limitations to agricultural production. First, with continued wetting and drying out, the soil has a tendency to accumulate high concentrations of salt. This problem is especially acute

in Iraq where between twenty and thrity percent of the cultivable land has to be abandoned each year due to salination. Second, the soils are very low in nitrogen content which is necessary to sustain high production in these soils. As a consequence of these two factors, the productivity of these soils tends to be exhausted rather quickly with the result that much of the cultivable land in these countries must be placed in fallow during alternate years. Further, even when these soils are used for cropping, the resulting yields tend to be quite low.

Clearly, then, to overcome this second obstacle constitutes another major prerequisite for increased agricultural production. But again, no single input will be sufficient to achieve this. Instead, there are several separate, but closely interrelated, inputs which will help to improve the suitability of the soils for production. Among these imputs is, of course, a drainage system for "flushing" harmful salts out of the soils. In conjunction with this, these countries need to improve their use of land and water. What this entails is the adoption of such practices as land leveling, flood control, and moisture conservation. Another major input has to be fertilizers, particularly nitrogen fertilizers. While potassium and phosphorous fertilizers are present in these countries, they are not available in sufficient amounts to sustain a wide variety of crops or high production levels. Finally, with increased fertilization and irrigation,

new varieties of crops could be introduced which are of the high-yield type.

All of the inputs identified above, including the extension of irrigation, are directed at raising the per acre yields of the cultivable lands in these countries. But raising per acre yields represents only one aspect of the overall problem of increasing agricultural production. Another, equally important aspect of this problem is that of raising the per capita productivity of labor. As we noted at the outset of this report, a major share of the labor force in each of the five countries is employed in the agricultural sector. Yet, the per capita productivity of this agricultural labor is presently quite low. Of course, faced with the lack of adequate water and soils, the individual farmer is not going to be very productive. But even with the necessary physical inputs to overcome these two obstacles, he is still not likely to be very productive. For to raise the per capita productivity of agricultural labor in these countries, two additional obstacles must be overcome. The first of these two obstacles relates to the availability of labor in sufficient amounts to support an intensive effort to expand agricultural production.

Of those employed in the agricultural sector, most all are engaged in traditional subsistence farming. With agricultural production thus being carried out primarily to meet the food needs of the individual house-hold (or production

unit), the labor input required to produce this food is provided principally by the household itself. More often than not, this labor is quite sufficient to meet the labor requirements for subsistence production. As a result, there is very little need for additional, nonhousehold labor. With the raising of the productivity of the cultivated lands, however, "...the need for labor will increase so considerably that present surpluses (if any exist at all) will hardly suffice to satisfy the new requirements."[8] Put somewhat differently, by raising per acre yields these countries create another problem for themselves, namely: the problem of a shortage of labor. There are no other sources of labor in sufficient amounts which these countries can draw upon to meet the new labor requirements. Moreover, the agricultural sector loses part of its labor supply each year as some farmers migrate to urban areas. Unless this shortage of labor can somehow be made up, it is likely to have an adverse affect on the efforts of these countries to improve land utilization, to expand agricultural production.

But how can these labor shortages be made up? One way to overcome this obstacle is to substitute machinery for labor, i.e., to "mechanize" agriculture. (The level of mechanization at present is rather low in these countries, with most farmers still depending on animal or human power.) By inputting more and better equipment (such as tractors) to replace human and animal power, these countries should be

able to increase the per capita productivity of the existing labor supply, and thus to decreaae the amount of labor required for the intensification of agricultural production.

To reiterate a point made earlier, however, the introduction of farm machinery (or of any other single input) is not by itself sufficient to bring about the desired changes in agricultural production: "... mechanization would accomplish relatively little unless accompanied by better irrigation and drainage, greater fertilizer use, better crop varieties, better control of weeds and crop diseases, and by other components of a technologically advanced agriculture..."[9] Nor is the mere inputting of these factors of production together enough. There must also be a willingness on the part of individual farmers to adopt these new production inputs. What this essentially boils down to is the existence of economic opportunities which are rewarding to these farmers. Herin lies the final obstacle to increased agricultural production to be discussed here, namely: the relative lack of such opportunities in these five countries.

As Schultz (1964) notes, traditional agriculture (which agriculture in these countries predominantly is) has certain built-in resistors to any change in the existing state of the arts: "The concept of traditional agriculture implies long-established routines with respect to all production activities."[10] Because farmers in traditional agriculture have a wealth of experience with these routines to draw

upon, the risks and uncertainties they face with regards to the production possibilities of traditional factors of production are minimal. But with the introduction of new factors of production, they are faced not only with having to break with the past, but also with having to cope with risks and uncertainties which are as yet unknown.[11] As a result, they are likely to be rather hesitant to adopt these new factors. Yet, only through experience will they be able to learn what the risks and uncertainilties inherent in these factors.

How, then, are those in traditional agriculture to be induced to try these new production inputs? The answer to this question lies in the economic opportunities which agricultural production and, in turn, the use of these new inputs offer to tne farmer. More precisely, the willingness of individual farmers to adopt the new production inputs depends upon (1) the payoffs to their production activities, and (2) the costs (as well as the supply) of these inputs. What this essentially means is that there must be a system of prices which will enable farmers to make a reasonable margin of profit and, at the same time, to obtain the necessary new inputs at prices that permit this profit margin. (It is this margin of profit, then, that provides the necessary inducement, or lack thereof, to adopt the new production inputs.) In the five countries examined here, however, such a system of prices is, for the most part, missing. Prices for farm products in these countries tend, in general, to be

depressed and distorted. Morever, the costs of the required inputs are still quite high. The overall effect of the present system of prices has thus been to leave farmers in these countries with very small margins of profit, if any at all. As a result, there is very little incentive for these farmers to produce much more than what is necessary to meet their own consumption needs. This, in turn, means that there is little incentive to purchase the new production inputs.

To overcome this obstacle to increased agricultural production requires, of course, the establishment of a more efficient system of prices. But again, the establishment of this price system is not enough by itself to bring about an increase in production. While such a system may lead to an increased desire on the part of farmers to seek to increase their outputs, their efforts will not get very far unless there are adequate aupplies of the necessary production inputs available. Put another way, the essence of agricultural development in these five Middle Eastern countries is

> ...the application of a package of separate <u>but closely interrelated</u> programs, technologies, and processes; it is their interrelationship which is truly significant... Any single program may have limited and sometimes even negative effect, if taken by itself; but may be highly productive if combined with other programs in proper proportions and proper timing.[12]

The problem facing the decision-makers in these countries is thus one of finding that combination of programs which will produce the results they seek. With this in mind we turn now to our proposed model of the agricultural sector.

THE MODEL

As the preceding discussion suggests, the effort to modernize and develop the agricultural sector in these five countries is clearly no simple matter. There are numerous physical, economic, social and political factors, the dynamic interactions between which affect the decision-makers' choices of developmental policies and programs. To provide a clearer picture of how this complex array of factors and their interrelationships affect these choices, we have constructed a simulation model of the agricultural sector in these countries. What one proposed model purports to offer is a way to (1) identify and trace the essential information and material flows influencing the choices of the decision-makers, and (2) analyze and project the consequences that their choices may possibly have for the performance of the agricultural sector.

For the sake of some simplicity, we have confined our attention in the construction of this model to the production of but one crop: wheat. Wheat constitutes the principal crop grown in these countries in terms of both the quantity produced and the amount of crop land devoted to it. Wheat also represents the major staple in the diets of the people in these countries. Taking these two facts into consideration, we feel that by limiting our view to this one crop we will still be able to present a fairly representative picture of the setting with in which decisions in the development of the agricultural sector are made in these oil-producing countries.

In constructing our simulation model of the wheat production process, we have employed a "building-block" approach.[13] With this approach, the complex array of variables and functional interrelationships comprising the agricultural sector are broken into several sequentially-linked "logical components" (or building-blocks) to simulate the various facets of the production process. There are four such components in our present model: resource allocation, modernization, production/marketing, and consumption/demand (See Figure 1). The output of each component serves either as an input to the next component in the sequence or as a measure of that component's performance. (It is the set of such performance measures which constitutes the input from the agricultural sector to the decision stratum).

What follows, then, is a brief description of the structure and functions of the four components of our model. This description will focus primarily on the mathematical form of the model. But to aid the reader in following through these equations, we have provided several "causal maps" of the interrelationships among the variables of the model. The key to interpreting these maps is as follows:

Symbol	Meaning
→	Denotes direction of influence or causality
○	Denotes endogenous variables
E	Denotes exogenous variables
P	Denotes policy variables
C	Denotes constants

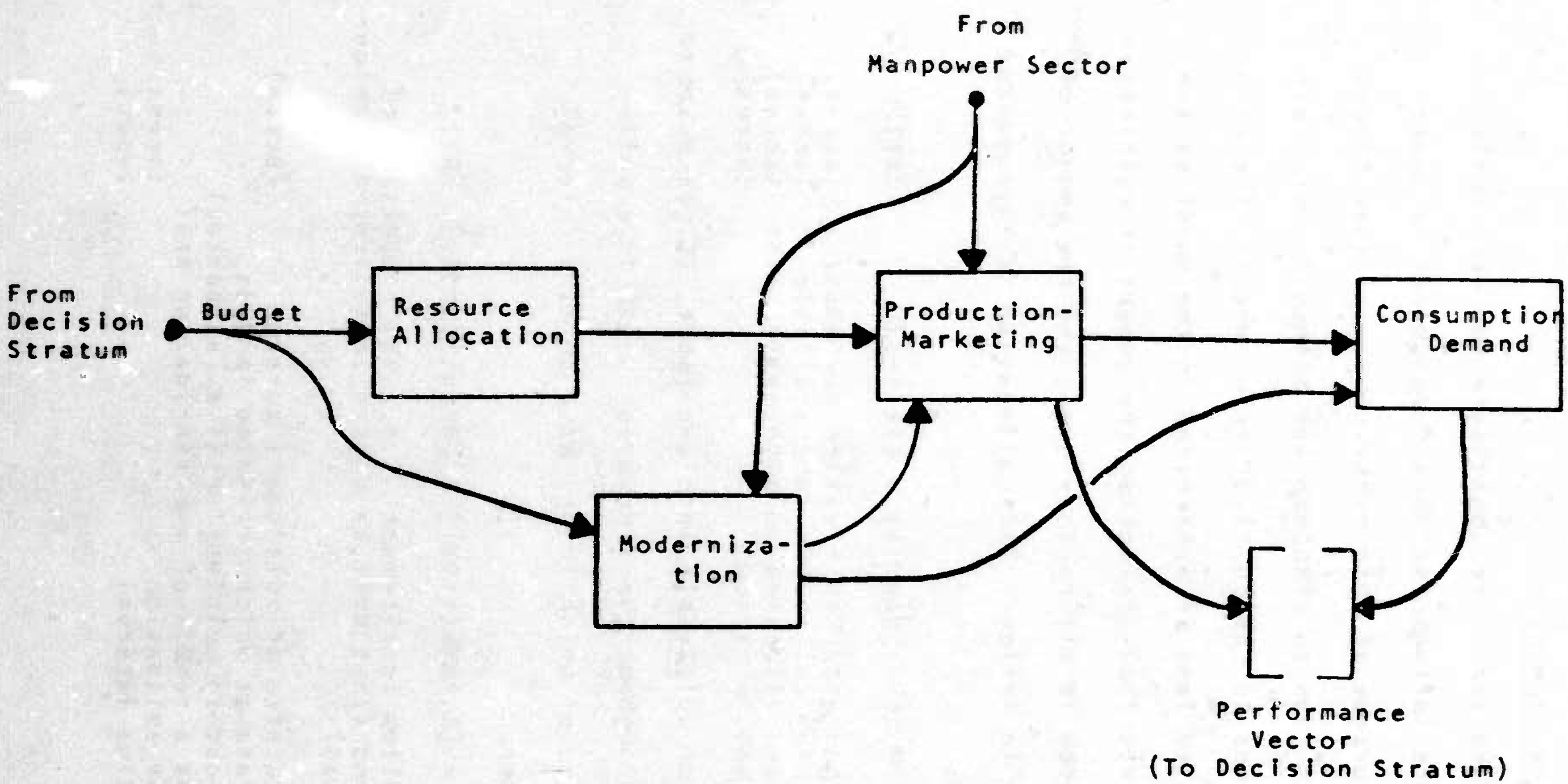


Figure 1. Major Component and Interacting of the Agricultural Sector Model

D   Denotes a delay function

Resource Allocation Component

Obviously, land and water constitute two very basic but crucial factors influencing wheat production in these countries. The purpose of this first component (See Figure 2) of the model is thus to simulate the allocation of these two scarce resources to the cultivation of wheat. The allocation of cultivated land is determined in the model by the amount of cultivable land available, the amount of cultivated land which is placed in alternative uses, and the amount of land that is left in fallow. This allocation is represented as follows:

$$LUC\ (t) = CL - [LAU\ (t) + LIR\ (t)] \qquad (R1)$$

where:

LUC	= land under cultivation for wheat	(acres)
CL	= total cultivable land available	(acres)
LAU	= land allocated to alternative uses	(acres)
LIR	= land in fallow	(acres)

The total amount of cultivable land available, CL, is assumed to be constant throughout the simulation. LAU is a policy variable, the value of which is set at each time interval by the policy maker.

$$LIR(t) = [C_1 * \overset{RFA}{\text{[redacted]}}(t-DT)] + [DT*RLI(t-DT)] \qquad (R2)$$

where:

C_1	= fallow requirement (i.e., the proportion of land (that must be placed in fallow)-dimensionless)	
RFA	= rainfed (traditional) acreage	(acres)
RLI	= rate at which irrigated land is lost to cultivation (i.e. exhausted) as a result of over-irrigation and/or salination	(acres/year)
DT	= time interval	(year)

with this variable, an endogenous variable, we are able to take into account the impact of farming practices on land utilization. In the case of rainfed land, for example, the principal farming system is one of alternating crops with fallow.

Much of the land under cultivation in these countries relies on rainfall for its water supply (variable RFA, which is computed by Equation R6). Of course, irrigation water is used in some areas. The development of an irrigation system, in fact, been a major policy of these countries. The rate of this development and the extent of irrigation in each country are computed by the following equation:

$$IRD\ (t) = \frac{1}{DEL}\left[\frac{BUDI(t)}{COST\ I(t)}\right] \qquad (R3)$$

$$IRP\ (t) = IRP\ (t-DT) + DT\left[\frac{1}{IRR} * IRD\ (t) - RLI\ (t)\right] \qquad (R4)$$

$$IRA\ (t) = IIR\ (t) * IRP\ (t) \qquad (R5)$$

$$RFA\ (t) = LUC\ (t) - IRA\ (t) \qquad (R6)$$

<u>where:</u>

IRD	= irrigation development rate	(acre-ft/year)
BUDI	= investment allocated to irrigation development	($)
COST I	= cost of irrigation water	($/acre-ft.)
DEL	= time delay	(years)
IRP	= potentially irrigatable acreage	(acres)
IRR	= irrigation requirement	(acre-ft/acre)
IRA	= acreage actually irrigated	(acres)
IIR	= intensity of irrigation	(dimensionless)

Of the above variables, IIR is perhaps the most hazily conceived. We have made it a policy variable in the model which ranges from 0 to 1.0. One might expect that these countries would try to make full use of their irrigation potential. Yet this is not the case. Iraq, for example, has in the past utilized only half

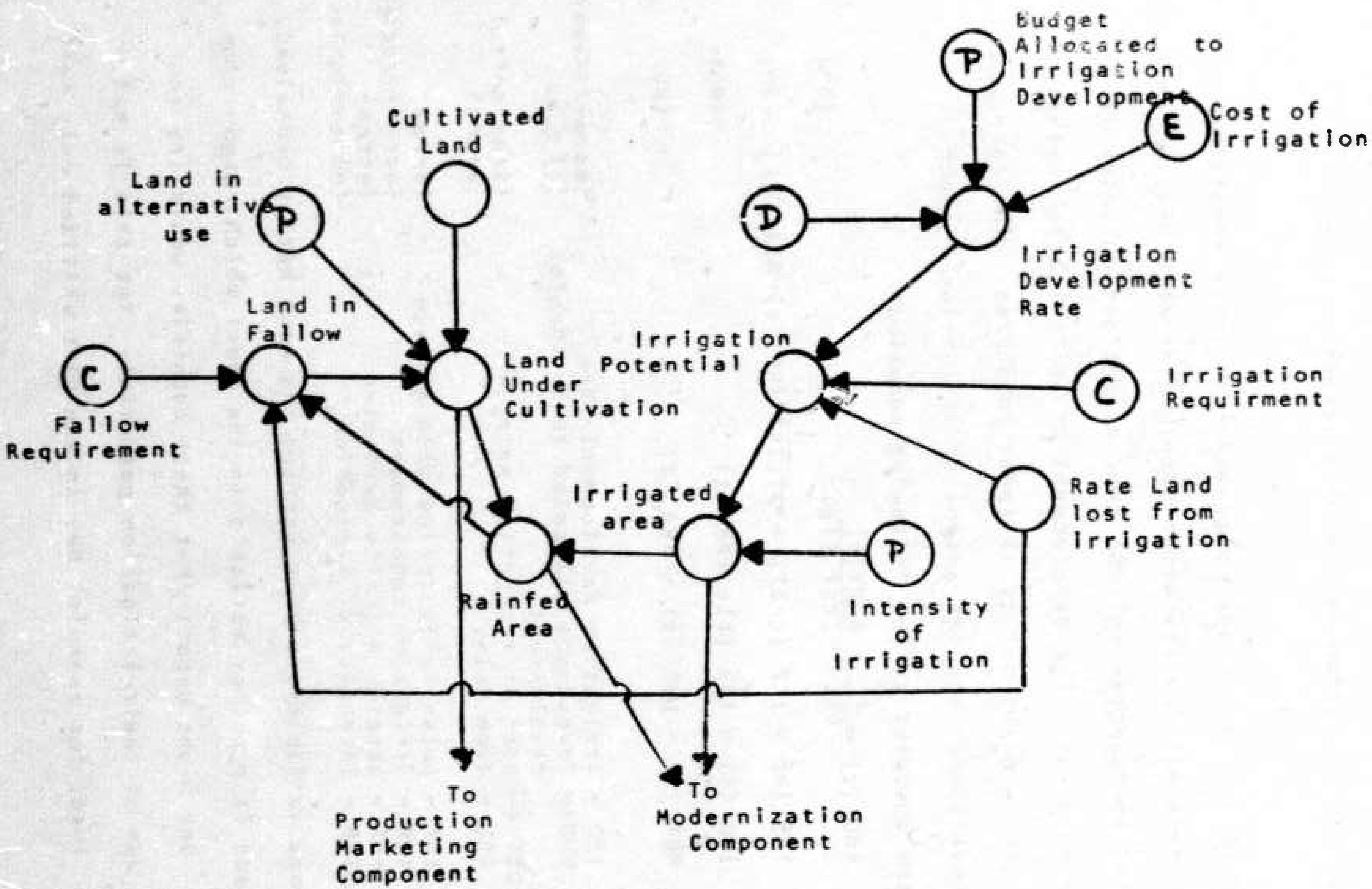


Figure 2. A Causal Map of the Resource Allocation Component

of their irrigation potential.

The variable IRR is a constant in the model, the value of which depends upon the growing season. For winter crops like wheat it is 4 acre-ft./acre; for summer crops this figure is 7 acre-ft./acre.[14]

The outputs of this resource allocation component are, then, the total amount of land under cultivation in wheat, the amount of this land which is actually irrigated, and the amount of cultivated land which depends on rainfall (i.e., traditional acreage) for water. All three outputs are inputs to the modernization component; only land under cultivation constitutes an input to the production/marketing component.

<u>The Modernization Component</u>

As we have noted on several occasions in this paper, the development of one input (e.g., water) is not by itself sufficient to bring about increased agricultural production. Instead, a number of different modernizing inputs are required to accomplish this including fertilizers, farm machinery, improve seed varieties, etc. In order to explore the impact of these modernizing inputs on the agricultural production, a "modernization" component has been included in the model. (See Figures 3a and 3b). This component focuses specifically on the impact of increased fertilization and mechanization on the production of wheat in these countries. The primary outputs of this component are 1) a measure of productivity (yield per acre), and 2) a mechanization coefficient. Both outputs

serve as inputs to the production/marketing component.

For the sake of clarity only, we have divided the modernization component into two parts. The first part to be described here concerns the introduction of fertilizers to the production process:

$$RFERT\ (t) = \frac{1}{DT} * [PCFERT\ (t-DT) * \frac{BUDF(t)}{PFERT(t)}] \quad (M1.1)$$

$$FERTC\ (t) = DT * RFERT\ (t) \quad (M1.2)$$

$$FERTA\ (t) = FERTC\ (t) /\ IRA\ (t) \quad (M1.3)$$

$$YPAM\ (t) = FRC\ (t) * FERTA\ (t) \quad (M1.4)$$

$$YPA\ (t) = \frac{[(YPAM(t)*IRA(t)) + (YPAT*RFA(t))]}{LUC(t)} \quad (M1.5)$$

<u>where</u>:

RFERT = the rate of fertilization, i.e. the amount of fertilizers obtained per year (lb/year)
BUDF = agricultural investment allocated to fertilization (dollars)
PFERT = the farm price for fertilizers (dollars/lb.)
PCFERT = the profitability criterion for fertilization (dimensionless)
FERTC = the total amount of fertilizer used (lb.)
FERTA = a measure of the intensity of fertilizer use (lb./acre)
YPAM = the productivity (yield per acre) of the irrigated (modern) crop area (bushels/acre)
YPAT = the average productivity (yield per acre) of the rainfed (traditional) crop area (bushels/acre)
FRC = fertilizer response coefficient (bushel/lb)[15]
PP = the producer (i.e., domestic) price of wheat (dollars/bushels)

With Equation M1.2, there is no provision for the accumulation of fertilizers over time. We assume here that because of the low quality of the soils in these countries, farmers will use all of the fertilizers they are able to get.

Whether or not the farmer makes full use of fertilizers, however, depends on more than the availability of fertilizers. Of equal if not greater importance is the profitability of using

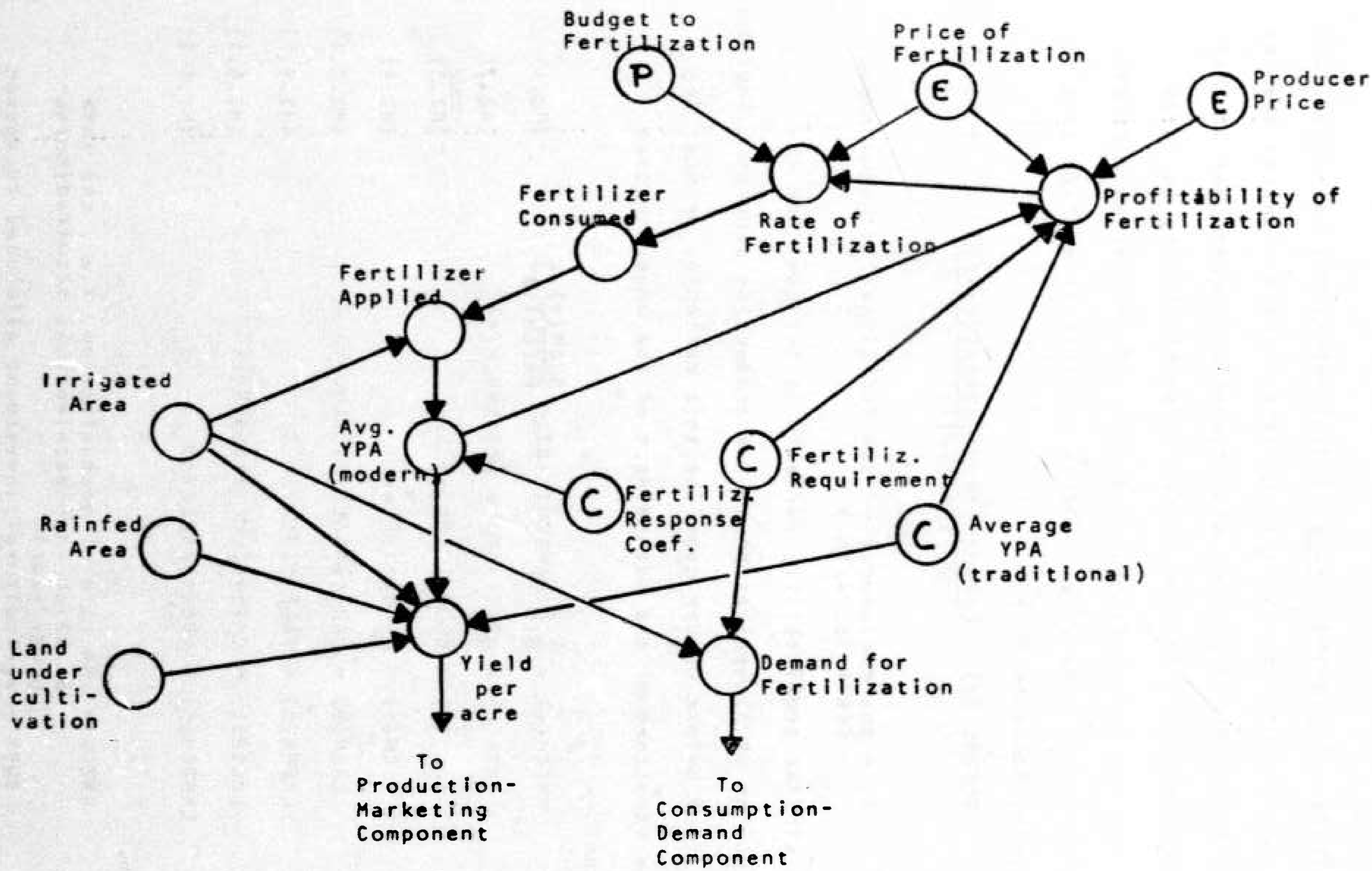


FIGURE. 3a. A Causal Map of the Modernization Component (Fertilization)

fertilizers. As Johnson, et.al (1971) noted, the modernization of the production process will not take place "...unless the net return from modern practices significantly exceeds that of traditional practices." 16 The impact of profitability is introduced into the model with the inclusion of the variable PCFERT (Equation M1.1). The value of this variable at a given time is computed by Equation M1.6.[17]

$$PCFERT\ (t) = \frac{[YPAM(t)*PP(t)-PFERT(t)/E1]}{YPAT*PP(t)} \qquad (M1.6)$$

where:

E1 = the reciprocal of the fertilization requirement, FERTR (acre/lb.)

A similar profitability variable is included for the introduction of machanization to the production process (Equation M2.7). But before we can describe this variable, we must lay out the structure of the second part of the modernization component:

$$RMECH(t) = \frac{1}{DT}[\ PCMECH(t-DT)*\ \frac{BUDM(t)}{PMECH(t)}] \qquad (M2.1)$$

$$ATP(t) = ATP(t-DT) + [DT*RMECH(t)] \qquad (M2.2)$$

$$POWU(t) = ATP(t)/LUC(t) \qquad (M2.3)$$

$$CM(t) = POWU(t)/POWR \qquad (M2.4)$$

$$LABM(t) = [CM(t)*SALF(t)]/LUC(t) \qquad (M2.5.1)$$

$$LABNM(t) = SALF(t)/LUC(t) \qquad (M2.5.2)$$

$$LMECH(t) = CM(t)*[LUC(t)/SALF(t)] \qquad (M2.6.1)$$

$$LNMECH(t) = LUC(t)/SALF(t) \qquad (M2.6.2)$$

where:

RMECH = the rate of mechanization, i.e., the rate at which farm machinery is acquired(horsepower/year)

BUDM = agricultural investment allocated to mechanization (dollars)

PMECH = farm price for machinery input (dollars/horsepower)

ATP = available tractor power (horsepower).[18]
POWU = power utilization (horsepower/acre)
POWR = power required for high yield crop production (horsepower/acre)
CM = coefficient for mechanization (dimensionless)
LABM = labor .nput with mechanization (men/acre)
LABNM = labor input without mechanization (men/acre)
LMECH = land-man ratio with mechanization (acres/man)
LNMECH = land-man ratio without mechanization (acres/man)
SALF = labor available, i.e., the size of the agricultural labor force (men)

The profitability criterion for mechanization, PCMECH, is then computed by the following equation:

$$PCMECH(t) = \frac{[LMECH(t)*AINCA(t)-PMECH(t)/E2]*LABNM(t)}{LNMECH(t)*AINCA(t)*LABM(t)} \quad (M2.7)$$

where:

AINCA = the average gross income per acre from crop production (dollars/acre)
E2 = the reciprocal of the power requirement, POWR (acre/horsepower)

Finally, the modernization component computes two additional output variables: (1) the demand for fertilizers, and (2), the demand for farm machinery. Both variables constitute inputs to the consumption/demand component. Moreover, both represent the quantities of input that are necessary for modernization to take place.[19] These demands are computed by the following two equations:

$$DFERT(t) = FERTR*IRA(t) \quad (M3.1)$$

$$DMECH(t) = POWR*LUC(t) \quad (M3.2)$$

where:

DFERT = the demand for fertilizers (lb)
DMECH = the demand for farm machinery (horsepower)
FERTR = the fertilization requirement (lb/acre)

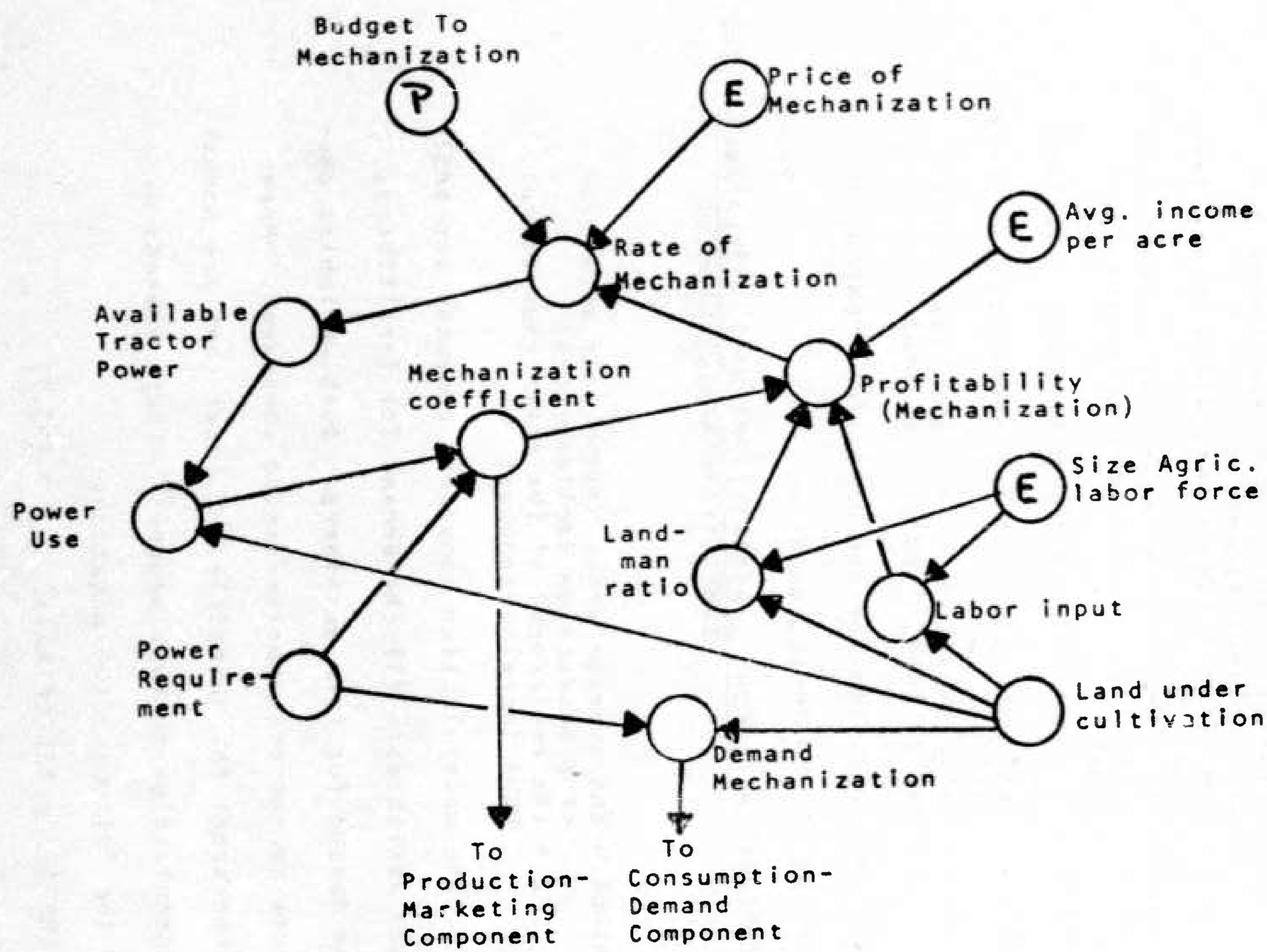


Figure 3b. A Causal Map of the Modernization Component (Mechanization)

The Production/Marketing Component

This component is somewhat misnamed in that marketing activities as such are not included in the structure of this component. The purpose of this component, then, is to simulate the activities of wheat production, and to compute the returns to these activities.

As the core of this component is a set of input-output relationships which are determined by the incoming land cultivated for wheat (from the resource allocation component), the labor available for crop production, the level of crop productivity and mechanization (from the modernization component). (See Figure 4). From this component emerges a set of physical outputs which then become inputs to the consumption/demand component. These outputs are computed by the following equations:[20]

$$YLDM(t) = LUC(t)*YPA(t) \qquad (P1)$$

$$DEML(t) = [C_2*LUC(t)]/CM(t) \qquad (P2)$$

$$YLDL(t) = \left[\frac{CM(t)*SALF(t)}{DEML(t)}\right]*YLDM(t) \qquad (P3)$$

$$YLD(t) = MIN[YLDM(t), YLDL(t)] \qquad (P4)$$

where:

- YLDM = the total production (yield) of wheat possible if YPA reaches the biological maximum (bushels/acre).[21]
- DEML = total labor required (demand) for the production of wheat (men)
- C_2 = labor requirement for cultivation (men/acre)
- YLDL = total production feasible as a function of labor (bushels)
- YLD = total production actually achieved (bushels)
- MIN(a,b) = a function that takes the minimum of turns in the parentheses.

With the information provided by these computations, the component then allocates the total production to the two physical output variables:

$$OUTC(t) = PCON(t)*YLD(t) \qquad (P5)$$

$$OUTE(t) = [1-PCON(t)]*YLD(t) \qquad (P6)$$

<u>where</u>:

OUTC = quantity of wheat produced which is allocated to domestic consumption (bushels)
OUTE = quantity of wheat produced which is available for export.
PCON = proportion of production allocated to domestic consumption; a policy variable expressed as a percentage.

In addition to these physical outputs, the production/marketing components computes several measures of the returns to the production activites. These measures, along with a measure of labor productivity, serve as inputs to the performance vector. The computations of these measures are accomplished as follows:

$$TINC(t) = [PP(t)*VLD(t)] - COST(t) \qquad (P7)$$

$$COST(t) = [PFERT(t)*FERTC(t)] + [PMECH* DT*RMECH(t)] \qquad (P8)$$

$$INCP(t) = TINC(t)/SALF(t) \qquad (P9)$$

$$INCA(t) = TINC(t)/LUC(t) \qquad (P10)$$

$$LABP(t) = YLD(t)/SALF(t) \qquad (P11)$$

<u>where</u>:

TINC = total gross income derived from wheat production (dollars)
COST = total farm cost of modernizing inputs(dollars)
INCP = per capita income from wheat production (dollars/man)
INCA = returns to land input (dollars/acre)
LABP = labor productivity (bushels/man)

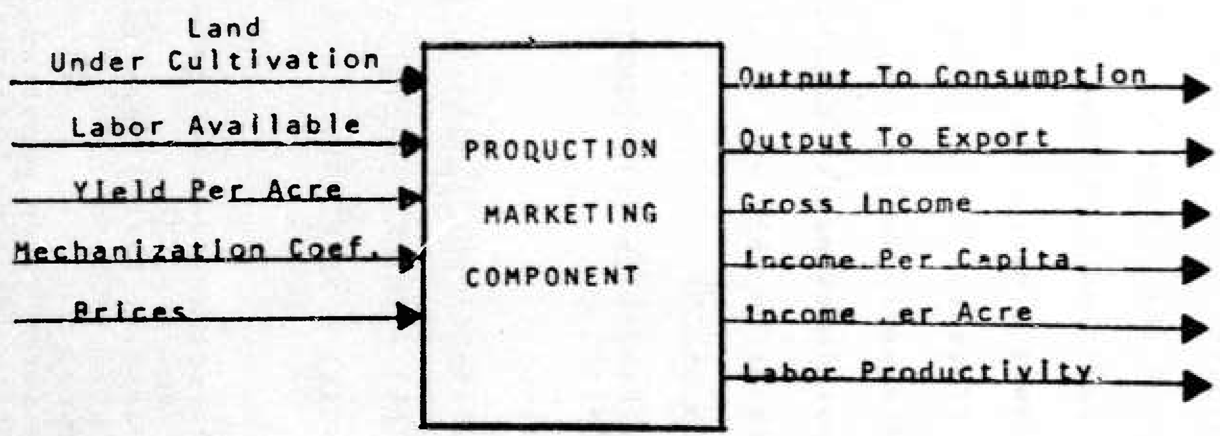


FIGURE 4. . Major Inputs and Outputs of the Production / Marketing Component

Consumption/Demand Component

This final component of our proposed model essentially represents a budgetary accounting mechanism. It take the information on modernizing input demands (from the modernization component) and production outputs (from the production/ marketing component), and computes the values for several variables measuring the overall performance of the production process being modelled. Put more simply, the purpose of this component is to compute the final set of variables comprising the performance vector. These variable include: 1) total demand for modernization input investments (Equation C1), 2) the value of crop exports (Equation C2), and 3) the demand for food imports (Equation C3,C4,C5).

$$\text{DEMAND I}(t) = [\text{COSTF}(t)*\text{DFERT}(t)]+[\text{COSTM}(t)*\text{DMECH}(t)] \qquad (C1)$$

$$\text{VALEXP}(t) = \text{WP}(t)*\text{OUTE}(t) \qquad (C2)$$

$$\text{DFOOD}(t) = \text{DFOOD}(t-DT)*[\frac{\text{POPI}(t)}{100}+\text{I.E}\ (\frac{\text{PCE}(t)}{\text{POPI}(t)}-1)]^{22} \qquad (C3)$$

$$\text{SUPPLY}(t) = \text{OUTC}(t) + \text{IMPORT}\ (t-DT) \qquad (C4)$$

$$\text{IMPORT}(t) = \text{DFOOD}(t) - \text{SUPPLY}(t) \qquad (C5)$$

where:

DEMAND I = total investment demand for modernization inputs (dollars)
COSTF = market cost of fertilizers (dollars/lb)
COSTM = market cost of farm (dollars/ horsepower)
VALEXP = total value of crop exported (dollars)
WP = world price for crop (dollars/bushel)
DFOOD = consumption demand for crop (bushels)
POPI = population index (dimensionless)
I.E. = income elasticity coefficient of demand for crop (dimensionless)
PCE = index of total private consumption expenditure (dimensionless)
SUPPLY = total available domestic supply of crop (bushels)
IMPORT = imports of crop (bushels)

Performance Vector

The choice of efficacious development policies and programs necessarily depends upon the decision-maker's understanding of the many varied aspects of the production process. Because of the very complexity of this process, however, the individual decision-maker is not likely to "see" a complete picture of this process; there is too much to be seen and too little information available on all aspects of the process. How then is one to evaluate the performance of the agricultural production process (and of his development efforts)? Upon what information does he base his choices of developmental policies and programs? The answer to both questions rest with the "performance vector". It is this vector (or set of variables) which measure the simulated system's attainment of "goods" and avoidance of "bads".[23] It is this set of variables, calculated in the salient components of the model, which serves as the input to the decision stratum.

Included in the performance vector of our proposed model are several factors measuring the returns from wheat production: gross income, per capita income, income per acre, and labor productivity. The set of variables comprising the performance vector is completed with inclusion of the outputs from the assumption/demand vector.

Discussion

Admittedly, the preceding description of our proposed agricultural sector model is somewhat sketchy. But then, the very nature of the subject matter and the modelling

approach employed make explanations difficult. We are dealing with a very complex system composed of countless variables and interrelationships. To try to present a complete picture of agricultural production would necessarily mean building a model which is so complex as to make it unmanageable. Of course, it is not our intention to build such a model nor is it our intention to limit ourselves to just one aspect (ie, wheat) of agricultural production in the countries of interest. Instead, we have attempted to construct a model which is general enough to simulate the production of a number of different crops.

There are, to be sure, some important shortcomings in our model, both substantively and technically. For example, the model does not deal adequately with marketing, the price system, and the behavior of the individual farmer. Moreover, several variables in the model have been rather hazily conceived (e.g. intensity of irrigation) with the result that the relationships between them and other variables in the model remain unclear. Some major changes may be required in the model to overcome these limitations. But we cannot be sure of what specific changes to make until after we have had an opportunity to test the present model. To this end, we are trying to complete the specification of the model's parameters (and the shape of the functional relations) for each country. The programming and testing of the model will follow shortly.

FOOTNOTES

1. Clawson, Marion, Hans Landsberg and Lyle Alexander (1971) The Agricultural Potential of the Middle East. New York: American Elsevier Publishing Co., Inc. p.2

2. Clawson, Landsberg and Alexander, p.37

3. ibid

4. Clawson, Landsberg and Alexander, p. 115

5. ibid

6. As Clawson, Landsberg and Alexander have indicated, it is estimated that the costs for producing groundwater from pumped deep wells runs between $250 and $370 per acre-foot (1971, p.115). In contract, Fried and Edlund (1971) suggest that with the development of a large-scale single purpose plant based on oil or gas, the cost of desalination could be brought down to around 25 to 35 cents per 1000 gallons.

7. Clawson, Landsberg and Alexander, p. 4

8. Brenner, Y.S. (1971) The Economics of Agricultural Development. Ithaca, N.Y.: Cornell University Press, p. 50

9. Clawson, Landsberg and Alexander, p. 41

10. Schultz, T.W. (1964) Transforming Traditional Agriculture New Haven: Yale University Press, p. 33

11. ibid

12. Clawson, Landsberg and Alexander, p. 111

13. By a "building block" approach, we refer specifically to the modelling approach developed by Glen Johnson, <u>et al</u> , namely "the generalized system simulation approach. As it <u>will</u> soon be apparent, we have relied very heavily upon this work of Johnson et.al. in constructing our model.

14. Clawson, Landsberg and Alexander (1971), p.135.

15. This coefficient represents the per unit relationships between fertilizer use and crop production. The value for this coefficient is determined by regressing crop production on fertilizer use (i.e. it is a regression coefficient).

16. Johnson, Glen, <u>et al</u> (1971) <u>A Generalized Simulation Approach to Agricultural Sector Analysis</u>. East Lansing: Michigan State University. p.49

17. This equation was derived from the profitability criterion variable formulated by Johnson et al (1971), p.89

18. Although a wide variety of machinery is required for modern agricultural production, we shall focus on tractors alone.

19. Underlying the calculation of these demands is the assumption that these inputs are not readily available - they must be imported - and as such do act to constrain the modernization effort.

20. These equations are a slightly modified version of those presented by Johnson et al (1971), p. 79.

21. The most reasonable estimate of this biological maximum is 100 bushels/acre (Clawson, Landsberg and Alexander, 1971, p. 122

22. Asfour, Edmond (1965) Saudi Arabia Beirut: American University of Beirut, p.25

23. Johnson, et al (1971), p.33

REFERENCES

1. Asfour Edmond Y. (1965) Saudi Arabia Beirut: American University of Beirut. Economic Research Institute

2. Brenner, Y.S. (1971) Agriculture and the Economic Development of Low-Income Countires. The Hagule: Mouton

3. Clawson, Marlon, Hans H. Landsberg, and Lyle T. Alexander (1971). The Agricultural Potential of the Middle East. New York: American Elsevier Publishing Company, Inc.

4. Day, Richard H. and Inderjit Sinch (1971) "A Microeconometric Study of Agricultural Development" SSRI Workshop Paper 7120, University of Wisconsin.

5. Fried, Jerome J. and Milton C. Edlund (1971) Desmalting Technilogy for Middle Eastern Agricultural: An Economic Case. New York: Praeler Publishers

6. Griffin, Keith B. (1965) "Algerian Agriculture in Transition" in I. William Zartman, Ed., Man, State, and Society in the Contemporary Magnrib (1973) New York: Praeger

7. Heesterman, A. R. G. (1970) Forecasting Models for National Economic Planning. Dordriecht - Holland: D. Reidel Pubisihing Company

8. Johnson, Glen, Etal. (1971) A Generalized Simulation Approach to Agricultural Sector Analysis, with Special Reference to Nigeria. East Lansing: Michigan State University

9. Kermani, Taghi (1967) Economic Development in Action: Theories, Problems, and Procedures as applies in the Middle East. Cleveland, N.Y.: World Publishing Co.

10. Mellor, John W. (1966) The Economics of Agricultural Development Ithica, N.Y.: Cornell University Press

11. Schultze, T.W. (1968) Economic Growth and Agriculture New York: McGraww-Hill Book Company

12. Schultze, T.W. (1964) Transforming Traditional Agriculture New Haven: Yale University Press

13. Singh, Inderjit (forthcoming) "Recursive Programming Models of Agricultural Development" in G.C. Judge and T. Takayama, leds., Studies in Space and Time, Amsterdam: North Holland

Theories and Forecasting in International Relations:
The Role of Validation Efforts

Charles F. Hermann
Warren R. Phillips
Stuart J. Thorson

Ohio State University

Project Research Paper No. 17

Paper prepared for the Conference on International Relations Forecasting, Massachusetts Institute of Technology, October 3-5, 1973.

The research described in this paper was supported by the Advanced Research Projects Agency Contract No. DAHC 15 73 C 0197.

THEORIES AND FORECASTING IN INTERNATIONAL RELATIONS: THE ROLE OF VALIDATION EFFORTS[1]

INTRODUCTION

Periodically, international relations scholars are urged to cast the results of their studies in terms of forecasts or expectations about the future. The reason seems clear enough. At some future point the forecasts can be compared against actual occurrences and based on the degree of confirmation the original research (or the researcher) can be evaluated. Moreover, if the forecasts have concerned the near future, the investigator can presumably use inadequate forecasts to revise his reasoning. New estimates of the future can be made and subsequently checked in a cyclical manner to produce successive approximations that hopefully achieve a continuously improved fit between forecast and subsequent observation. What is more, if the forecast obtains acceptance, it becomes the basis for prescriptive action. Humans thus participate consciously in shaping their future and engage in self-fulfilling or self-denying forecasting. ("If certain occurrences will happen, we need to undertake the actions to promote, obstruct or take advantage of them.") Perhaps few proponents of greater forecasting in international relations would state their case in such unqualified terms, but the above description appears to capture the core of such arguments. The argument has

[1]The authors acknowledge the support of the Mershon Center and the Center for the Study of Theoretical Politics in the preparation of this chapter.

much merit. A forecast that is stated in such a way as to permit its verification against the unfolding future provides one type of criterion for validity.[2]

The difficulties arise in moving from these simple statements of aspiration to the development of insights and procedures that can be applied in research. At the point of actually validating forecasts a host of philisophical and practical questions arise. What is it that the forecast represents? Or, put a different way, assuming that a forecast could be validated, what does it mean? How does purpose affect the validation of a forecast? What validation procedures can be employed? What about inconsistencies between the results of forecasts and other means of validating a theory? How can one confidently know (and measure) the future reference system when one sees it? These questions tip off the reader to the conclusions to be found at the end of this chapter. Using forecasts as a validation procedure is much more complex and the results less certain than appears at first glance. Nevertheless, it is an important, if insufficient, operation for improving our knowledge of international relations. For that reason, the following pages seek to provide some initial exploration of the issues posed by these questions and where possible to suggest some possible procedures.

---

2 See C.F. Hermann, "Validation Problems in Games and Simulations with Special Reference to Models of International Politics," Behavioral Science 12 (May 1967), 216-231.

THEORY AS THE GENERATOR OF FORECASTS

Assume that we momentarily set aside the problems of determining how a forecast is valid, one question that remains is what do we know when we have a validated forecast? In such circumstances, we would know that a particular estimate made at some prior time has been confirmed to some degree by subsequent developments. This confirmation of forecasts can be variously referred to as validation, goodness of fit, verisimilitude, isomorphism, verification, or accuracy. Beyond this information about the relationship between the forecast and actual events, however, we frequently want to infer something about the means and the source by which the forecast was generated. More specifically, we might normally wish to infer something about the ability of that source to generate other forecasts. ("Carl was correct in anticipating the outcome of this week's soccer game, but will his judgment be as good for next week's match?") In this simple example, the inference is about the ability of an individual to make a forecast. Unless he was making an ungrounded guess, the forecaster performed some calculations that formed the basis of his estimate. As long as they remain unarticulated we know very little about the mental images or models that generated the forecast. Policy makers also have mental images which they use in estimating the future. For example, an expert on the Soviet Union probably has mental models of how political decisions are made in that country. He could use these images in evaluating the alternative future policies that the USSR might take on a given issue. Similarly, scholars also use mental models or images which delineate the problems they should attack and the likely approaches to delineating forecasts in a particular

substantive domain. These mental images are frequently relied upon; unfortunately there are major problems associated with this form of forecasting with respect to establishing the validity of its source. Different researchers have different mental images, each dealing with a wide range of overlapping substantive interests, and each frequently inconsistent with the others. We are faced with difficulties in knowing which images are applicable in a specific case. The sources of contradiction may not be obvious, because the relationships in each image are not clearly defined. The lack of explicitness in mental images makes it difficult to communicate the assumptions upon which any forecasts are based. In cases in which disputes about alternative outcomes actually are recognized, unidentified assumptions implicit in the mental images that researchers hold frequently are the cause of these differences. Perhaps more importantly in long range projections, it is difficult to manipulate the variables in mental images in order to assess the various impacts of individual changes that could operate on the initial conditions. Thus, the complexity of social phenomena makes it extremely difficult to move from a vague set of assumptions about the world through the dynamic consequences resulting from these assumptions to various forecasting alternatives.

As many chapters in this book make clear there are numerous ways of generating forecasts. The unexplicated mental images in the minds of one or more individuals are only one such means but they are a frequent one in international relations. They deserve attention not only because of their frequency but because they illustrate a basic problem. When one or more forecasts are used as a means of validating the utility of

an explanatory source for subsequent forecasts and explanations, the components of the forecasting system and their logical relationships to one another must be explicit. Otherwise, what can be inferred about the validity of any future performances of the system will be quite limited. In short, we assert that in order to use forecast validation as a means for inferring the future predictive capability of the source, the source should have the characteristics of a deductive theory. Such a requirement certainly limits the range of sources that can be subjected to validity estimates through forecasts. Nevertheless, the requirement of a deductive theory as the source of forecasts seems appropriate, if our validity studies must take into account the following considerations:

(1) Forecasts are used to estimate the utility of the source for future forecasts.

(2) It is necessary to establish the parameters or boundaries beyond which the source may decline sharply with respect to the accuracy of its forecasts.

(3) The forecast concerns a dynamic reference system that is suspected of containing some components that can assume a substantial range of values which in turn may yield quite variant outcomes.

We believe these are conditions that frequently confront the international relations scholar who evaluates the validity of forecasts.

Before proceeding further, it would be desirable to offer some definitions of the basic terms we have been using. A <u>deductive theory</u> is stipulated as a set of sentences which is closed under deduction; that is, the set contains any sentence that is logically implied by

any other sentence in the set. Generally the sentences in a theory are asserted to be true (of some world).

A _forecast_ is generally thought to be a statement made at one time about the state of some world at some future time. Thus the theories to be considered for forecasting must be dynamic theories in the sense that the values (states) of some variables are related to values of other variables at other points in time.

More precisely, consider a theory about some world consisting of state variables $(x_1, x_2 \ldots x_n)$. We want our theory to contain sentences relating at least some of these state variables to previous states of the system. In physics, for example, these sentences are often expressed in differential equations of the form:

$$\frac{dx}{dt} = f_1\ (x_1, x_2 \ldots x_n)$$

An example of a theory of this type drawn from the international relations literature would be the theory of arms races developed by Richardson.[3] Here again differential equations are used to relate a nation's level of defense at one time to system states at previous times.

A second example might be the world simulation described by Forrester.[4] The sentences are in the DYNAMO language and levels of variables at one time are related to levels at previous times. This time, the statements are in difference equations form.

---

[3]See L.F. Richardson, _Arms and Insecurity_ (Pittsburgh: Boxwood Press, 1960) and L.F. Richardson, _Statistics of Deadly Quarrels_ (Pittsburgh: Boxwood Press, 1960).

[4]J.W. Forrester, _World Dynamics_ (Cambridge: Wright-Allen, 1971)

In principle, a theory need not be expressed in an artificial language (such as DYNAMO or differential equations) to be a member of the class being discussed. Theories expressed in a natual language, such as English, may also satisfy the above conditions. It might be argued, for example, that Galtung's "rank theory" meets the criteria set out above.[5] A problem with most natural language theories (including Galtung's) is that it is very difficult to unambiguously identify the objects and relations being discussed.

Specifically excluded from the analysis that follows will be means of generating forecasts which are not "dynamic" theories of the sort identified above. Thus, trend and cyclical analyses that simply project prior patterns without any antecendent explanations are excluded. So too are the development of speculative or plausible scenarios, Delphi techniques, and the various devices associated with assessing the validity of measures (as for example in the psychological test and measurement literature). All have a role in forecasting in international relations. But evaluation of the validity of the forecast from such sources has limited utility for theory development.

Now that the class of theories to be discussed has been identified, it is appropriate to specify the concept of validity which will be employed in this chapter. In discussing a concept such as validity it is important to distinguish between semantic and methodological questions of how it becomes known whether a particular theory is, in fact, valid. Answers to the methodological question would seem to presume adequate answers to the semantic one. Therefore, the first task will be to explicate what will be meant in this chapter when validity is predicted

---

[5] J. Galtung, "A Structural Theory of Aggression," Journal of Peace Research 2 (1964), 95-119.

of a theory. A theory--a set of sentences in some language--is valid if it does what it purports to do. Thus, as is noted by Forrester[6] and Hermann[7] the question of validity is inextricably intertwined with the purpose to which (in this case) a forecasting system will be put. A number of possible purposes and criteria of validity appropriate to these purposes will be treated subsequently. However, we can now state the semantic conception of validity being employed in this chapter. A theory, T, is valid with respect to purpose P, to the extent T achieves P. Relating validity to purpose, is, of course, compatible with an extremely pragmatic view of theory evaluation. This compatibility, however, does not require that we adopt such a pragmatic view. One might argue, for example, that the purpose of a scientific theory is to generate (or be capable of generating) true sentences.[8] Thus, the test of validity of a scientific theory is whether the sentences comprising the theory (as well as those logically implied by these sentences) are true. That is to say, for a scientist taking this position to assert that T is a valid theory is equivalent to his asserting that the sentences comprising T are true. Note again that this semantic definition of validity does not entail any particular methodological position as to how a particular theory is known to be valid (i.e., known to consist of true sentences). For example, it might be argued that the goal of

---

[6] J.W. Forrester, Industrial Dynamics (Cambridge: MIT Press, 1961).

[7] C.F. Hermann, "Validation Problems in Games and Simulations."

[8] See K.R. Popper, Conjectures and Refutations: The Growth of Scientific Knowledge (New York: Harper Torchbooks, 1965), pp. 223 ff.

science is to construct true theories (i.e., theories whose sentences are true) and yet still argue that it can never be known whether any particular sentence is in fact true and therefore be some sort of falsificationist rather than a verificationist.

The important point here is that the validity of a theory is contingent upon its purpose(s) and therefore it makes little sense to inquire of the validity of a theory without inquiring as to its purpose(s). Purpose is just one of the factors that affect the relationship between a forecast and the theory used to generate it. The most important of these issues must be considered in greater detail.

SOME CONSIDERATIONS AFFECTING THE RELATIONSHIP BETWEEN THEORY AND FORECAST

Let us take a brief review. The theories of interest in this chapter must generate forecasts, that is, statements concerning changes in the values of objects at different points in time. We contend in this chapter that the question of forecast validity is actually one of using the forecast to assess the validity of the theory that generated the predictions. The assertion that under certain conditions a particular pattern of events will occur during some future period of time suggests an obvious criterion for establishing validity of the theory. If the specified conditions transpired, did the projected pattern occur as predicted? The accuracy of forecasts is certainly an essential feature of the validation effort, but a number of issues must be taken into account in evaluating the relationship between a theory and its forecasts.

As we noted at the end of the previous section, no discussion of the factors that affect the interpretation of the relationship between forecast validity and the theory which generated it would be complete without consideration of the purpose the user intends to make of both the theory and the forecasts. Any interpretation of the accuracy of a forecast as an indicator of the adequacy of a theory must be evaluated in terms of the purposes of the user. As purposes vary so does the degree of tolerance in goodness of fit between forecasts and observed patterns of events. In fact, the user's purpose should determine whether inferences about the theory from confirmed forecasts are of major importance. Elsewhere some distinctive purposes of simulations (one type of theory) have been described together with their implications for validity. Among the purposes mentioned were (a) the discovery of alternatives, (b) the evaluation of alternative outcomes, (c) prediction, (d) instruction, (e) construction of hypotheses and theory, and (f) the exploration of non-existent universes. For the present, however, we need only establish that the user's purpose will make a difference. For example, if the user seeks explanation for why certain events transpire, then the confirmed forecast may be of minimal value in assessing a theory's adequacy. It is quite possible for a theory involving a number of stochastic processes to yield accurate forecasts about a closed system without providing much insight into why the observed pattern occurs when it does. With respect to the degree of accuracy in forecasting, numerous illustrations come to mind. A scholar developing a theory which estimates the rate of interaction between nations of opposing military alliances given various levels of interstate conflict in the international system may find

support for his theory in a goodness of fit ratio that remains quite modest. On the other hand, a theory that estimated the number of ICBM launchers that could be built by either the Soveit Union or the United States without detection by the other side would have to have a much better predictive capability if it were to be used as the basis for signing, or not signing, an arms limitation agreement. In assessing the degree of accuracy necessary for the user's purpose, one criterion must be the alternatives available for forecasting. In statistical tests forecast performance is often compared to chance, but that may not be the relevant standard in a particular case.

Another issue we must address is probability as opposed to determinism in the theory. Suppose we have a theory which leads to the following assertion: When nations of the world are ranked according to military and economic capability, the first-ranked nation will always initiate war with the second-ranked nation, if--and only if--the latter's rate of growth in both military and economic capability relative to the first-ranked nation will lead to a reversal of ranks within five years. Such a statement can be contrasted with one which concludes that the first-ranked nation is <u>more likely</u> to initiate war against the second if its projected economic and military growth rate will cause it to overtake the first-ranked nation within five years. The first statement claims to contain all the conditions that are necessary to produce the projected outcome and that the outcome occurs every time the conditions are met. The second assertion contends only that the specified conditions increase the likelihood of the outcome. Although the example may seem a bit far-fetched, some theories can

generate forecasts which are held to be completely determined by the configuration of specified conditions; whereas others are probabilistic theories, the most sophisticated of which may be able to estimate the probability associated with different possible outcomes.[9] When the theory's specified prior conditions are not related in a deterministic fashion to the estimated outcome, a forecasting exercise cannot provide insight into the theory's degree of validity without consideration of the impact of exogenous variables. Moreover, even in the case of the deterministic theory, the lack of congruity between forecast and outcome may lead no further than to recasting the relationship in probabilistic terms.

A deterministic theory yields a set of expected values in some future state but makes no provision for the outcome if the expected values do not occur. It is as if our theory projected the rate of desent of a ball of a certain mass down an inclined plane having an angle that is a certain number of degrees from horizontal, but taking no account of friction,the resulting air density, the surface of the plane and ball, etc. Or, consider the example of theory that projects that a certain rate of economic development in a less developed country will begin, at a given point, to generate a certain amount of capital. These theories neglect what happens if the forecasts are not fulfilled-- the amount of friction drastically slows the ball or internal revolution

[9] The distinction between the projected outcomes from probabilistic as compared to deterministic theories overlaps somewhat with Choucri's distinction between predictions and forecasts. We maintain, however, that a deterministic theory could still produce a forecast in Choucri's sense of the term. See her discussion in Chapter 1.

slows capital formation. If the distribution of outcomes around the projected one involves only gradual deviations, we still might give the theory "high marks" even if slight errors occur. If the distribution of outcomes surrounding the one that is forecasted falls off sharply, then a deterministic theory poses severe problems--particularly if the forecasted outcome is regarded as desirable and those around it appear undesirable. Thus, for example, instead of capital formation a country experiences revolution. Therefore, although forecasts of a deterministic theory may more readily be tested for their validity, inaccuracies may be more difficult to interpret (i.e., how far off is the actual outcome?) and pose serious difficulties for some purposes (e.g., policy analysis).

There is a counterpart in the reference system to the deterministic-probabilistic characteristic of theories. We must consider the actual distribution of the forecasted events in international relations. Are the occurrences considered unique and non-current or are they repeated regularly? Examples of the former include the death of Mao or the acquisition of nuclear weapons by Japan. Whereas the latter include such things as changes in political leadership of a country or the rate of diffusion of a technology If the phenomena that are the subject of the theory reoccur in the reference system, we need to take into account the frequency of their appearance. Are they frequent occurrences--such as diplomatic exchanges or trade negotiations--or relatively less frequent--such as inter-state wars or global economic depressions? Suppose that a theory's forecast of the probability of the outbreak of war under certain conditions is .75 and in subsequent actuality the conditions

are fulfilled but no war occurs. Over a series of such forecasts we could establish whether the forecasts correspond to events three-fourths of the time, provided that the class of predicted events occurred with sufficient regularity together with the set of conditions specified in the theory. Then we would have a situation comparable to that used in weather forecasts of precipitation. ("The probability of rain in the next 24 hours is 80 percent--or more precisely, the probability of precipitation is 80 percent under conditions such as those that are expected to prevail in this locality during the next 24 hours.") Unfortunately, there are numerous events in international relations that do not occur with the frequency with which rain falls on many parts of the earth. Thus, we have a situation in which a theory can predict a pattern of occurrences which do not occur in the real world with sufficient regularity to assess with confidence the forecasts.

One thoughtful critic has charged that in his previous writing on the subject, the first author has failed to consider that an error in forecasting (or other criteria for validating a model) can result from a misinterpretation of the reference system--or "real world"--rather than from an inadequate model.[10] The charge highlights another problem in the inferential relationship between forecasts and theory. When an incongruity exists between forecasts and subsequent developments, one might ask whether it results from the theory--let us call it theory X--that led to the forecasts or the theory--designated

[10] See Charles A. Powell, "Validity in Complex Experimentation," <u>Experimental Studies in Politics</u> (1973).

theory Y--used to observe and interpret the reference system? When an astronomer calculates from deflections in the movement of other bodies in our solar system that a previously undetected planet should be observable at a certain point in space and none is found, is the astronomer's theory of the missing planet wrong or should we re-examine the theory of optics or the theory for locating other objects in space relative to the earth? If a simulation forecasts a certain pattern of national economic growth which is not substantiated in subsequent economic activity as measured by the Gross National Product, do we re-examine the simulation or the indicator of actual economic performance?

Certainly, a committed scientist ought to consider all such avenues in cases of unconfirmed forecasts. It ought to be possible for him to develop a strategy for determining which explanation for the lack of a confirmed forecast he should pursue first. (Has the theory of optics been substantiated independently in other tests? Does the present test use GNP in ways the measure has not previously been used?) Given the relative newness of simulations in international relations and the restricted presentation that exists in any simulation, it is easy to conclude that inaccurate forecasts are indicative of inadequate simulations. Perhaps, such inferences are too easy. Our conceptualizations and observation techniques in international relations have seldom been confirmed in a systematic fashion. In a given area of international relations there may be no definition of the key concepts, no explicit statement of assumptions, and very elastic measures of observation. Under such circumstances, the scholar must be acutely sensitive to the possibility that his means for verifying the forecasts require careful examination.

Although it is always desirable to check the theories of observation and interpretation used in confirming forecasts, the tendency to do so is greater the more discrepancy occurs between forecast and subsequent events. Another type of problem arises in instances in which the goodness of fit between forecast and events seems substantial. How confidently can we infer from such verisimilitude to the theory assumed to have accounted for the observed developments? There is the possibility that the correspondence of events and forecasts is the product of a spurious correlation, coincidence, or an overdetermined event. The appearance of a substantial goodness of fit that actually results from fortuity should be eliminated by repeated forecasting attempts that would reveal the coincidence as random error. Repeated tests should also reveal those situations which are overdetermined--that is, outcomes that result from any of several different factors and all of which happen to be present in a given instance. Across a variety of forecast occasions, some of the relevant exogenous conditions may not occur, and those accounted for in the theory will be responsible for the observed result. Somewhat more troublesome is the systematic error in the form of a spurious correlation. Although repeated forecast efforts may reveal the presence of this problem, one can put the theory in an operational form--or simulation--and conduct sensitivity tests to determine the effects of individual components on the outcome when other elements are held constant.

The reference to sensitivity testing as a means of checking on spurious correlations that might explain a high degree of accuracy in a forecast openly makes a point applicable to all the issues discussed

in this section. In order to clarify these problems that can affect the assumed relationship between a forecast and the theory that generated it, we must examine directly the theory. For spurious correlations we want to conduct sensitivity tests on the theory. To determine the implications for forecasting of the user's purpose, we need to examine the theory for its correspondence with such purposes. If we have a deterministic theory, we need to identify with special care the exogenous variables not contained in the theory that could alter the forecast. Should the theory predict rare events in the reference system, we need to establish estimates of our confidence in the theory independently of its forecasts of those infrequent occurrences. (We will return to this point in the discussion of plausibility in the next section.) Again, in deciding between errors in theories that generate forecasts and errors in theories involved in assessing the actual occurrences in international politics, we must move outside the forecasts themselves. In short, issues that can affect our inferences about theory which are made from confirmed forecasts require us to deal directly with the source. This observation is one reason why we contend that validity of more than the forecast itself requires that the source of the forecast be an explicit theory. Unless the source of the forecast reveals its components and their relationships, resolution of the issues discussed in this section often becomes impossible.

VALIDATING THE FORECASTS

Assuming that we want to make inferences about the future predictive capability of the source of a forecast (a theory) and that we can manage

the kinds of difficulties outlined in the previous section, the task remains of determining the accuracy or goodness of fit between the forecast and subsequent events. After all it is from this degree of congruence that we move to inferences about the theory that generated the forecast. In this section we consider two aspects of validating forecasts--plausibility and empirical verification.

Although validation is often thought of as exclusively an empirical exercise, at the time a forecast is made it attempts to describe future events for which we have no immediate empirical validation capability. Because this is the case, and because the careful validation of forecasts can often be expensive in time and money, we ought to satisfy ourselves that such an effort is justified. Of course, this justification depends in part on the user's purpose. It should also depend on the plausibility of the forecasts, that is, the contextual constraints which must not be exceeded if forecasts are to be taken seriously. We might begin by considering the caution of Newell and Simon who observe:

> The plausibility of a fundamental hypothesis about the world is almost always time-dependent. Hypotheses are seldom plausible when they are new and have not yet been widely accepted. If empirical evidence supports a hypothesis increasingly, and if the hypothesis succeeds in providing explanations for a significant range of phenomena it becomes more and more plausible.[11]

[11] A. Newell and H.A. Simon, Human Problem Solving (Englewood Cliffs, N.J.: Prentice Hall, 1972),p. 19.

This psychological relationship between "plausibility" and "empirical success" mitigates against using plausibility as a sole criterion for validating forecasts. Nevertheless, as Kanter and Thorson[12] note, we would not advocate important policy changes in our actions if the theoretically predicted consequences were not at least plausible. Because this is the case, plausibility is likely to be a necessary although certainly not a sufficient condition for evaluating the validity of a forecast. Such is especially true when our forecast assumes policy relevance.

One method of estimating plausibility is to consult with people who deal with the empirical domain being projected. Policy planners, for example, often have expectations about the phenomena with which they operate routinely and they make informal judgments regarding the probable consequences of actions. The evaluation of these experts offers a valuable source of information. Indeed, this is likely to be an area where the policy maker has a comparative advantage to which social scientists interested in making policy inputs will have to pay more attention in the future.

Another method of testing plausibility is to see whether the forecast violates any logical constraints. Occasionally, a theory which generates plausible forecasts when the values of variables are held to expected or previous levels yields absurd results if certain values exceed "normal" levels. For example, education planners argued for a theory which predicted exponential enrollment growth. Predictions from

---

[12] A. Kanter and S.J. Thorson, "The Weapons Procurement Process: Choosing Among Competing Theories," Public Policy 20 (Fall 1972).

the theory seemed to fit the data very well until about 1969. After that point the model predicted exceedingly larger student enrollments. By the year 2050 the number of U.S. college students was predicted to exceed the total predicted population of the United States.[13] Systems stressing of this kind is frequently ignored becasue the theory makes quite plausible predictions in shorter time frames or for more normal ranges of events. A "quick and dirty" sensitivity test may reveal that much of the process about which a theory forecasts is not yet understood.

Turning to the empirical aspects of validation, one of the important questions concerns how much of a theory need be included in the statistical attempts at verification. In complex theories with a large number of variables, one possible strategy is to treat the theory in subdivisions with forecasts from each module. Obviously in large, rich theories it would be desirbale from both a financial aspect as well as a logical aspect to test subsections independently. Computer costs reach astronomical levels when the number of variables and interrelationships becomes large. In addition, it becomes increasingly difficult to identify the reason for errors in forecasts when using numerous variables. This problem is especially acute when we have reason to believe that the independent variables are not linearly independent of each other.[14] Ando, Fisher

---

[13] This example is described more fully in A. Kanter and S.J. Thorson, "The Weapons Procurement Process."

[14] See N.R. Draper and H. Smith, Applied Regression Analysis (New York: Wiley, 1968) and M. Ezekiel and K.A. Fox, Methods of Correlational Regression Analysis (New York: Wiley, 1959).

and Simon[15], however, have demonstrated that if we are dealing with linear systems in our theory and our system is completely decomposable (that is, the variance to be accounted for is explanable by the variables in each decomposed subset), we will not do an injustice to our theory by validating each of the subsections independently. They proceed to show that it is more frequently the case that the subsystems are only partially decomposable (most, but not all, variance is explanable by variables within the subset). In such cases the subsystems can be treated independently only over short periods of time. Over long periods of time interaction between subsystems becomes dominant. Thus in longer range forecasting it is generally an unwise strategy to attempt to break a theory into more manageable subsets having fewer variables. This conclusion is similar to that of George who suggests that, at least for policy-making, theories with more variables may have greater utility.[16]

The number of statistical techniques potentially useful in testing the validity of forecasts is extremely large.[17] Most of them require additional assumptions not required in cross-sectional analysis, however. For example, if we want to determine the relative importance of particular

---

[15] A. Ando, F.M. Fisher, and H.A. Simon, eds., Essays on the Structure of Social Science Models (Cambridge: MIT Press, 1963).

[16] A. George, "Introduction," in A.L. George, D.K. Hall and W.R. Simons The Limits of Coercive Diplomacy (Boston: Little Brown, 1971), p. xvi.

[17] For discussion of specific tests, see T.H. Naylor and J.M. Finger, "Validation," in T.H. Naylor, ed., Computer Simulation Experiments with Models of Economic Systems (New York: Wiley, 1971), Chapter 5.

independent variables using normal variance accounting techniques, generally the ordinary least squares is not an appropriate technique for testing the significance of each variable. Hibbs[18] states that if auto correlation occurs in our disturbance terms, ordinary least squares leads to a serious overestimation of the impact of independent variables. This impact can be subdivided into two particular classes. In the first case, when there are no lag variables in the analysis, the overestimation effects do not influence the prediction of the regression coefficient but they do affect the importance of the t test or the multiple R^2. In the second case where lag variables are included in the analysis, not only are the above affects noticed, but the actual level of the regression coefficients is influenced in such a way that usually the non-lagged variables' importance is decreased and the lag variable's importance is increased. These increases and decreases can be of a magnitude of three to four hundred percent.

Another factor in the validation of forecasts from a theory is the need for consistency in the level of aggregation employed in the theory, the forecast, and the test data. If, for instance, the unit of time employed in our forecast is the foreign policy act but the data are aggregated into monthly or yearly units, the identification of the true explanatory variables is difficult.[19] The reason is that the across

---

[18] D.A. Hibbs, "Problems of Statistical Estimation and Causal Inference in Dynamic, Time-Series Regression Models." Paper prepared for delivery at the 1972 meetings of the American Political Science Association, Washington, D.C.

[19] J. Johnston, Econometric Methods (New York: McGraw-Hill, 1972), especially Chapter 12.

time fluctuations considered important in making forecasts are lost or obscured in the larger units of analysis.[20] That particularly novel results can be achieved without due consideration of the theoretical implications for choosing different time frames or making differing assumptions about the auto regressive affects of error is certainly not a new finding. Yule[21] demonstrated that varying the lags in one's data can produce contradictory expectations.

The importance of the Ando and Fisher theory,[22] the summary of auto correlative effects by Hibbs[23] and the levels of analysis problem is that particular care must be taken when one begins the statistical validation of forecasts. It is important to keep in mind that we cannot simply rely on statistical analysis free from theoretical concerns to derive a validated forecast.

---

[20] G.M. Orcutt, H.W. Watts, and J.B. Edwards, "Data Aggregation and Information Loss," American Economic Review 68 (September 1968).

[21] G.U. Yule, "Why Do We Sometimes Get Nonsense Correlations Between Time-Series?" Journal of the Royal Statistical Society, LXXXIX (January 1926).

[22] A. Ando, F.M. Fisher, and H.A. Simon, Essays on the Structure of Social Science Models.

[23] D.A. Hibbs, "Problems of Statistical Estimation."

SUMMARY AND CONCLUSIONS

This chapter has attempted to develop a series of observations about the validation of forecasts. They are summarized in the following numbered points.

1. Often our interest in confirming forecasts in international relations is to facilitate our judgment about the source of the forecast. For example, we may wish to evaluate the source in order to establish our confidence in its ability to make future forecasts.

2. A number of factors can affect the relationship between the forecast and the source that generated it leading to incorrect inferences about the source. Among these problems are the effects of the user's purpose, whether the generating theory is deterministic or probabilistic, the frequency of occurrence of the forecasted events in international relations, the adequacy of the theories for measurement and interpretation of the reference system, and the confirmation of the forecast by properties other than those used in making the projection.

3. These obstructions to reasonable inference about the source can often be assessed if we can examine and test the source of the forecast in various ways. Such independent testing of the source is possible only if the components of the theory and their relationship are known and precisely defined. For this reason, we contend that the source of the forecast must

be a deductive theory. Other sources of forecasts in international relations may produce valid forecasts and play a vital role. But problems will be encountered with them if we try to systematically assess their potential for subsequent forecasting efforts.

4. The task remains of determining the validity of the forecast, that is, the goodness of fit between the theory's projection of the future value of certain variables and the subsequent unfolding of actual occurrences as defined in terms of the user's purpose. Before beginning empirical testing, some efforts should be made to determine if the forecast is within contextual constraints, that is, whether it is plausible. Empirical testing with statistical techniques can follow, but the investigator should be mindful of several factors--such as consistency in level of analysis--that can influence his results.

Adaptation and Foreign Policy Theory

Stuart J. Thorson
Department of Political Science
Ohio State University

September 1973
Project Research Report No. 18

Paper prepared for delivery forthcoming (Rev. Ed.) in Sage International Yearbook for Foreign Policy Studies.

Prepared in connection with research supported by the Advanced Research Projects Agency, ARPA Order No. 2345-3D20, Contract No. DAHC 15 73 C 0197, RF 3527-A1.

INTRODUCTION

The idea that foreign policy behaviors are in some sense the result of "adaptive" foreign policy "mechanisms" is a popular one. We read in the newspapers, for example, that United States foreign policy toward Israel must adapt to the "realities" of the energy crisis. Students of foreign policy behavior argue that nations like cells can be viewed "as entities that must adapt to their environments to survive and prosper (Rosenau, 1970:2)."

The notion underlying these and other such statements (see for example Easton, 1965, 1966; Deutsch,(1966); or McGowan, 1971) appears to be largely metaphorical. Human collectivities like infrahuman species either survive or they do not. If they are to survive they must somehow adapt to the external (or task) environment in which they find themselves.

In a very loose sense then, a nation is adaptive if it manages to "get along" in its environment. However, as has been argued in more detail elsewhere (Thorson, 1973), this is not a precise enough concept to guide theoretical research on national foreign policy behavior. For example, it does not distinguish between behaviors which are adaptive and behaviors which are generated by adaptive mechanisms. Adaptive mechanisms may behave maladaptively in "learning" appropriate responses. In using the concept of adaptation in discussing foreign policy, we must make precise of what "adaptiveness" is being predicated. Hopefully these distinctions (as well as the need for making them) will become more clear as this paper progresses.

First, however, it is important to briefly outline what sort of "theory" of foreign policy behavior it is reasonable to look for at this time. In doing this, we can distinguish between what Nelson and Winter (1973) have called "appreciative" theory and what has been called "formal" theory.

A theory in the formal sense consists of a set of sentences asserted to be true which is closed under deduction. That is, the set contains any sentence that is logically implied by any of the other sentences in the set. This usage requires a preassigned logical framework or "calculus" axioms which serve as the rules for moving from some sentences to others. These rules are ordinarily those of the first-order predicate calculus. Axiomatic theories are theories in the formal sense.

While formal theory might be an aim for many of us, few would argue that we presently have such theories of foreign policy behavior. Such theory as does exist is more of the appreciative sort. Appreciative theory is rather fuzzy in its deductive structure and its concepts often are intuitive rather than well defined. Nonetheless, as Nelson and Winter point out, it is the appreciative theory which guides most of the research effort in a discipline. It provides the concepts and a perspective from which to view and study phenomena without actually making precise analytic connections between statements.

Formal theory can then be built upon appreciative theory to make precise propositions and to eliminate some of the ambiguity inherent in the appreciative theory.

In this paper I will attempt the beginnings of an appreciative theory of national foreign policy behavior. The concept of adaptive or goal-oriented behavior will be central in the development of the theory. My major purpose, however, will be less to make a deductively related set of propositions about foreign policy behavior and more to identify a set of concepts and relations which may, through additional research, be capable of entering into a formal theory.

SYSTEM AND ADAPTATION

The problem of how nations generate appropriate foreign policy behaviors is in many senses analogous to the problem of how human beings generate grammatical sentences. In both cases, the theorist has a finite set of observations which he attempts to account for through general laws. In the case of the linguist, these finite observations consist of sentences and the general laws are called the grammar. As Chomsky, 1956:113, points out, "A properly formulated grammar should define unambiguously the set of grammatical sentences."

The theorist of foreign policy behavior has a similar task. He must attempt to account for a finite set of observed behaviors through some general theory of foreign policy behavior. Like the linguist, he can accomplish this task by identifying the rules (i.e., the "grammar") for generating these behaviors. That is to say, he must concentrate on the structural (my usage of structure is non-standard in political science and will be defined in a rigorous way further on) characteristics underlying the foreign policy behavior.

Note that we already face a difficulty. The linguist wants to account for sentences. The behavior unit is the sentence. What is the behavior to be accounted for by the foreign policy theorist? The "event?", sequences of "events?", some subset of "events?", or what? Without taking a position on this most central question, progress toward appreciative theory can still be made by making a rather innocuous (though perhaps erroneous) assumption that the foreign policy behavior of nations is goal directed.

Such an assumption is certainly consistent with Hanrieder's (1967: 971) rather vague definition of foreign policy as "... the more or less coordinated strategy with which institutionally designated decision-makers seek to manipulate the international environment." This consistency, of course, requires the additional restriction that these manipulations are made not willy-nilly but with some intended direction.

In turn, this restriction suggests immediately the question, "Intended by whom?" The need for such a question (as well as for its answer) is pointed up by Allison's (1971:162) observation:

> The decisions and actions of government are intranational political resultants: resultants in the sense that what happens is not chosen as a solution to a problem but rather results from compromise, conflict and confusion of officials with diverse interests and unequal influences; political in the sense that the activity from which decisions and actions emerge is best characterized as bargaining along regularized channels among individual members of the government.

This observation is important in that it warns us not to look at revealed national behavior (i.e., policy actions) and attempts to infer the national goals that the actions were designed to meet. Indeed it may well be that national policy goals (to the extent there are any) are better thought of as constraints on policy actions than as objectives those actions are designed to further. In Simon's (1964:1) words, "The goal of an action is seldom unitary, but generally consists of a whole set of constraints the action must satisfy." Ellsberg's (1972:102) description of United States policy objective in Vietnam as being "Do not lose the rest of Vietnam to Communist control before the next election" is illustrative of this. This objective served as a constraint on allowable policies and not as an operational goal around which one could design specific policy actions.

Thus, I am arguing that the foreign policy behavior generated by a nation is goal directed in the sense that the actors whose arguing, scheming, and compromising produced the policy each intended that the policy do (or perhaps "not do") certain things. These produced behaviors will seldom be "optimal". That is, the analyst can not look to a set of "national goals" and a set of "policy alternatives" and predict the alternative to be chosen will be the alternative which best achieves the goal.

Such an approach is wrongheaded for several reasons. First it assumes the existence of a consistent set of rational foreign policy goals which guide actor's decisions. Second, it assumes that all (feasible) policy alternatives can be listed. Third, and perhaps most erroneously, it assumes that there is an unambiguous performance function which can link policy actions to goals.

However, it is not necessary to assume that a nation's foreign policy behavior is "globally rational" in this economic optimizing sense. Rather we need simply assume that the behavior is goal directed

in the sense that looking at the goals of the individuals who interact to produce policy will help to account for the produced policy. In looking at these actor's goals, we must, of course, be careful not to look only at their foreign policy goals. Their bureaucratic goals, for example, will play a crucial role in determining their policy preferences.[1]

Moreover, to assume that foreign policy behavior is goal directed is by no means equivalent to saying that a nation will achieve its foreign policy objectives. Or, as was noted earlier, to say that a nation is an adaptive system is not to say that it will behave adaptively.

Leaving aside for a moment this problem of goals, it will be helpful to identify more precisely the general sort of structure underlying adaptive systems. I will be using a systems vocabulary because it contains a fairly well-defined set of terms which, I believe, can be profitably interpreted in a foreign policy framework and imbedded into a theory of foreign policy behavior. Therefore, I will first define some basic systems concepts and will then discuss goal-seeking systems in terms of this vocabulary. In so doing, it should become clear that to use a systems vocabulary imposes very little additional structure and any results which follow will generally not be an artifact of having adopted a systems approach.

In theorizing about any phenomenon (be it foreign policy behavior, ethics, or whatever) a first step is to isolate a set of "objects" about which you will be theorizing. Each of these objects may in turn take on a number of values. Each of these values can be termed an

"appearance" of the object. A simple example of such an object might be international conflict. Suppose that our theory partitioned international conflict into three values or "appearances"--low, medium, and high. Mathematically, we can think of the object "international conflict" as a set consisting of three elements. Each element of the set corresponds to one of the possible appearances of the object.

More generally, theories will be about worlds with "n" objects, $X_1, X_2, \ldots X_n$. A general system, S, is then defined as a relation on the cartesian product of these objects (i.e., sets).

$$S \subset X_1 \otimes X_2 \otimes X_3 \otimes \ldots X_n$$

The Cartesian produce of an n sets (denoted $X_1 \otimes X_2 \otimes \ldots X_n$) is the set of all ordered n-tuples $\langle x_1, x_2, \ldots x_n \rangle$ where $x_1 \in X_1$, $x_2 \in X_2$ $\ldots x_n \in X_n$. A relation on the Cartesian product of n sets is simply a subset of the set of all ordered n-tuples. These definitions will become clearer below when an example is presented.

Thus far, the definition of a system makes no mention of inputs and outputs. A system has simply been defined very abstractly as a subset of the set of all possible appearances of the set of objects being theorized about. The problem is to get from this definition to the familiar black box diagram with inputs X and outputs Y.

This problem is resolved by first defining an index set:

$$I = (1,2,\ldots n)$$

and then partioning I into:

$$I_x = (I_1, I_2, \ldots I_m)$$

$$I_y = (I_{m+1}, I_{m+2}, \ldots I_n)$$

Since this is a partition,

$$I_x \cup I_y = I \quad \text{and}$$

$$I_x \cap I_y = \emptyset$$

Then define an input set U:

$$X = (x_i \forall_i \in I_x)$$

and an output set Y:

$$Y = (x_i \forall_i \in I_y)$$

A system is now defined as a relation on (i.e., a subset of) the Cartesian product of the inputs and outputs, or:

$$S \subset X \otimes Y$$

This may all seem excessively abstract. However, such a definition makes it very difficult to fall into the trap of reifying systems. A system is something the theorist imputes on the objects he believes make up the world. That a system can be imputed reflects the constraints on the allowable conjunctions of appearances the states in the theorist's world are allowed to evince.[2]

A simple example will help to make these points more transparent. It will also be helpful to have it to refer back to later in the paper. In order that it serve the required illustrative functions, the example will be highly stylized.

Imagine a system S with inputs X and outputs Y as in Figure 1

$$X \longrightarrow \boxed{S} \longrightarrow Y$$

Figure 1

Suppose further that S is a nation's foreign policy generating mechanism and X is the mechanism's categorization of behaviors received from the world political environment. Y then can represent the "friendliness"

of the nation's foreign policy output. Equation (1) shows the relationship between X and Y (the "t" subscript refers to time).

$$\text{(I)} \quad Y_{(t+1)} = Y_{(t)} + X_{(t)} \qquad 0 \leq t \leq 1$$

So far there are two objects, X and Y. Let:

$$\text{(II)} \quad \begin{array}{l} Y_{(0)} \in (0, +1) \\ X_{(t)} \in (-1,+1) \end{array}$$

Thus given $Y_{(0)}$, we can specify $X_{(0)}$, and $X_{(1)}$ and compute using (I) $Y_{(1)}$, and $Y_{(2)}$. In order to make more sense of the example, interpretations can be assigned the various values of X and Y as in Table

Interpretations of Values of X and Y

X	Y
1 = friendly	-3 = Very Unfriendly
-1 = unfriendly	-2 = Unfriendly
	-1 = Mildly Unfriendly
	0 = Neutral
	+1 = Mildly Friendly
	+2 = Friendly
	+3 = Very Friendly

The inputs are specified by the sequence $(X_{(0)}, X_{(1)})$ and the outputs by the sequence $(Y_{(0)}, Y_{(1)}, Y_{(2)})$. The possible input sequences are:

$$\begin{aligned} X &= \text{(possible input sequences)} \\ &= \{(-1,-1), (-1,+1), (+1,-1), (+1,+1)\} \end{aligned}$$

The possible foreign policy output sequences are:

$$Y = \text{(possible output sequences)}$$
$$= \{(0,-1,-2),\ (0,-1,0),\ (0,1,0),\ (0,1,2),$$
$$(1,0,-1),(1,0,1),(1,2,1),(1,2,3)\}$$

The output sequence (0,-1,-2), for example, can be interpreted as a neutral output followed by a mildly unfriendly output followed by a unfriendly output.

In terms of the vocabulary developed earlier, the system has eight appearances.

$$S \quad X \otimes Y$$
$$S = \{[(-1,-1),\ (0,-1,-2)],\ [(-1,-1),(1,0,-1)],$$
$$[(-1,+1),(0,-1,0)],[(-1,+1),(1,0,1)],$$
$$[(+1,-1),(0,1,0)],[(+1,-1),(12,1)]$$
$$[(+1,+1),(0,1,2)],[(+1,+1),(1,2,3,)]\}$$

Note however that even given these eight appearances, a knowledge of input strings is not enough to accurately predict the output strings that will be produced. For example, the input string (-1,-1) will produce either the output string (0,-1,-2) or the string (1,0,-1). In mathematical terms, S is a relation and not a function.

In order to make the outputs predictable, more information is required. This additional information is termed the "state" of the system:

$$S\colon\ Z \otimes X \rightarrow Y$$

where Z is the state object. In the example, $Z = \{y_0\} = \{0,1\}$. As can be seen from the table of eight system appearances, a knowledge of the input strings <u>and</u> of the state (i.e., values of y_0) of the system

is enough to predict the output strings of the system.

The above discussion of "system," "state," "input" and "output," while abstract is, I believe, of importance to the student of foreign policy behavior. First of all, whether a particular nation's behavior is viewed as being stochastic or deterministic may be solely dependent upon how (if at all) the state of the system is defined. If the analyst ignores the internal structure of the behavior mechanism, he may well be lead to assert that equivalent inputs produce different behaviors. Yet, as the example showed, a proper selection of state objects might be enough to "make" the system deterministic. Simply correlating inputs and outputs (behaviors received and behaviors sent) will generally not yield laws of foreign policy behavior.

Second, the abstract notion of a system as a relation on the Cartesian product of objects (i.e., sets of appearances), forces the theorist to specify the objects about which he is theorizing. All too often, especially in theories expressed in a natural language such as English, the tendency is to assume that "everyone knows" what we are theorizing about. Since "everyone knows", there is no need to specify explicitly what objects make up that world. Yet, I think most would agree that we theorize not about the world but about our "representation" of the world. Since each of us may have a different representation of the world (or, indeed, there may be many worlds), it is always helpful to make public that representation by specifying it as unambiguously as possible.

This specification can begin by writing down the objects(and their possible appearances) which populate the representation. It is

completed when, in addition, the theoretically allowable conjunctions of appearances are specified. The fact that the set of logically possible conjunctions of appearances is greater than the set of theoretically allowable conjunctions is what gives structure to the world and allows scientific theorizing to be at all successful. Writing down the world being theorized about is equivalent (under the terminology of this paper) to specifying the system the theory is about.

An adaptive system is generally thought of as one which produces (generates, evinces) outputs in such a way as to seek to attain certain goals. Adaptive systems are goal seeking systems. Thus my earlier assumption that foreign policy behavior is goal directed entails that foreign policy generating mechanisms can be viewed as adaptive systems.

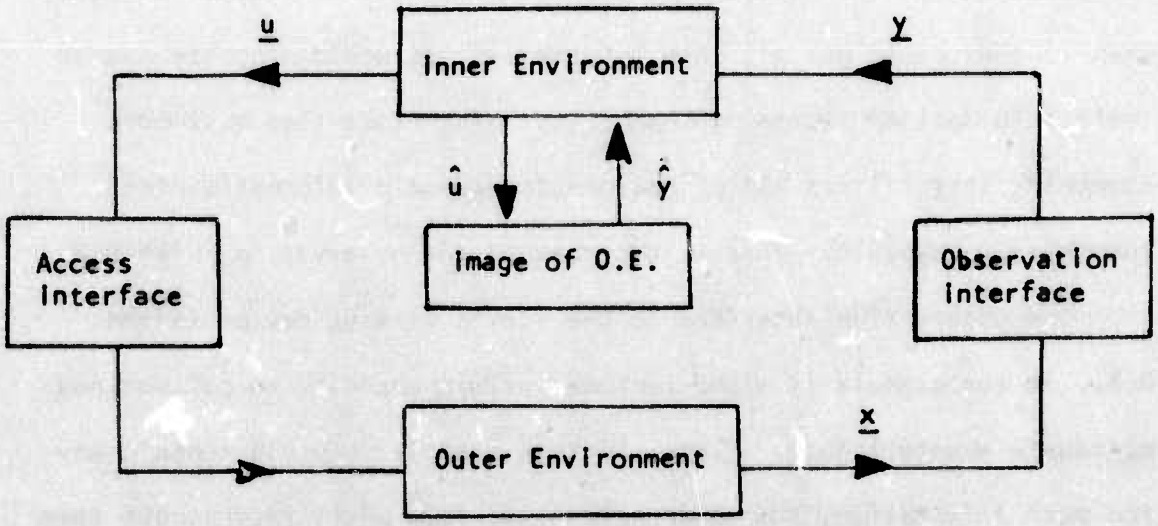
Adaptive systems belong to the class of systems labelled by Simon, 1969, as artificial systems.[3] While distinguishing between "artificial" and "natural" systems is not always easy (or even unambiguous), the central notion is that artificial systems are directed toward human goals whereas natural ones may not be. According to Simon, 1969:5,6:

> "1. Artificial things are synthesized (though not always or usually with full forethought) by man.
>
> 2. Artificial things may imitate appearances in natural things while lacking, in one or many respects, the reality of the latter.
>
> 3. Artificial things may be characterized in terms of functions, goals, adaptation.

4. Artificial things are often discussed, particularly when they are being designed, in terms of imperatives as well as descriptives."

An artificial system has a number of components. There is an inner environment (I.E.) which is attempting to achieve goals in an outer or task environment (O.E.). The I.E. receives information about the O.E. through an observation interface and sends policies or behaviors into the O.E. through an access interface. Finally, in order to evaluate alternative policies (without actually implementing them) the I.E. must have a representation or "image" of the outer environment. The structure common to artificial systems is shown in figure 2

Figure 2



This structure is very similar to the problem structure studied by control engineers. From a control perspective, the I.E. would be labelled the "controller" and the O.E. as the "process" to be controlled.

The easiest way to motivate this is through a very simple example. Let the inner environment (I.E.) be a country's officials responsible for economic policy and the outer environment (O.E.) be the country's economy. Let me stimulate further that the officials' goal is to remain in office and that they seek to do so by keeping the economic system in a certain specified set of acceptable states. The state of the economy is then represented by the vector $\underline{x}$ and might include such things as each citizen's income, all sales transactions, and other such elements.

The officials must have some way of observing $\underline{x}$ so that they can determine whether the economy is in an acceptable state. However, they can observe each and every sales transaction, etc. directly. In fact, even if they could get all this information, it would probably exceed their information processing capability. Therefore they must have something that filters all of the minute economic information into something manageable. This is the task of the observation interface.

The observation interface is the I.E.'s sensing device in the O.E.. In the example it might include various agencies to collect and aggregate economic data. Since, in this example, $\underline{x}$ would contain way too much information, the observation interface might incorporate some sort of indicator system. Thus instead of having $\underline{x}$ as an input, the I.E. receives $\underline{y}$. The vector $\underline{y}$ might include such indicators as GNP and unemployment rates. In some cases $\underline{y}$ and $\underline{x}$ will be equivalent. Most often, however, this will not be the case and the notation reflects this possible distinction.

Upon receiving $\underline{y}$, the I.E. must evaluate it to determine what sort of policy is indicated. The results of this evaluation will depend in part upon I.E.'s image of the O.E.. The image might, for example, consist of a Walrasian equilibrium model of the economy. Generally, this image will, at least in part, contain the elements of $\underline{y}$. In this way $\underline{y}$ can be used to set the "state" of the image and various policy alternatives $(\hat{\underline{u}})$ can be put into the image to assess their differential impacts $(\hat{y})$.

The elements of the $\underline{u}$ vector, to have any impact, must have some way of getting into the O.E.; that is, the I.E. must have some access interface which is capable of implementing $\underline{u}$ in the O.E. Fiscal and monetary policy might serve as accesses for the officials in this example.

This very crude economic example hopefully makes more clear the basic components of an artificial system. In addition, it should serve to illustrate the high degree of inter-relation between the components.

This example was <u>not</u> intended to suggest that the components of an artificial system will have simple "real" world interpretations. The distinctions between the components is analytic and it may be that the vocabulary generally used in theorizing about foreign policy is incapable of reflecting these distinctions. In using artificial systems concepts to construct empirically grounded theory, it may be necessary to develop some new terminology.

The artificial system's perspective suggested here requires the theorist to distinguish between the foreign policy "mechanism" and the outer environment in which the mechaninism must operate. This notion of "mechanism" can be related to the inner environment by stipulating that the inner environment together with the goals and the two interfaces will be referred to as "the mechanism." The outer environment (while definitionally remaining a primitive) then represents the external influences operating on the mechanism.

Depending upon the particular policy objectives being pursued, certain of the O.E. "influences" will be of special significance and will have a large (though not necessarily perceived) impact upon the mechanisms policy actions. These "influences" can be thought of as forming a specific subsystem of the O.E.. These subsystems are, of course, conditioned upon certain goals. Such subsystems can be termed "task environments" for the mechanism. As goals change, the mechanism will then be "facing" different task environments. While the O.E. is the global environment in which the mechanism must behave, the task environment is the particular problem solving situation faced by the mechanism. The mechanism may of course be pursuing multiple (and even inconsistent) goals and thus be facing multiple (and perhaps overlapping) task environments. The important distinction being made here is between the task environment and the outer environment. The outer environment consists of the total environment in which the mechanism operates. The task environment is the specific part of the O.E. which becomes important for a particular goal or policy action. "It is the task that defines the point of view about an environment, and that, in fact, allows

an environment to be delimited (Newell and Simon, 1972:55)."

As an example, one might view the U.S. foreign policy making mechanism to be operating in a very "large" outer environment. Included in this outer environment might be such elements as other foreign policy generating mechanisms, domestic political groups, multi-national businesses and so on. Yet for a particular task - say the development of a weapon system - only a small part of the whole O.E. is relevant. This smaller part is the task environment.

While the analytic distinction between the mechanism and its task environment may be clear, we must further distinguish between the task environment itself and the mechanism's internal image(s) or representation(s) of that environment. Here again one must pay careful attention to the internal structure of the mechanism for often times it is this structuring which will determine the mechanism's behavior.

The way(s) a problem is represented within the mechanism will play a major role in determining which policy behaviors will be seen. Within a foreign policy bureaucracy, this internal problem representation often takes the form of common images of reality on the part of bureaucrats.

Halperin and Kanter (1973) argue that these shared images serve as constraints on participants' ability to produce desired policy actions. As support for this claim, they provide the following example ". . . In the early 1950's, those in the Department of State who advocated forcing the Chinese Nationalists off Quemoy and Matsu could not support their case by advancing the argument that this would result in a substantial improvement of relations between the United States and Communist China. Since improved relations between the two countries was not a widely

shared goal, such an argument would have been counterproductive(1973:25)."

While this illustration does point out how shared goals may constrain arguments for particular policies, it fails to suggest how shared images of reality constrain policy actions. Indeed I have already claimed that "goals" may be thought of as constraints. Yet, of course, constraints are determined not only by "goals". Policy makers' images of their task environment will also constrain their behavior. That is, policies which might be infeasible under one image may become feasible under a second. For example, it is doubtful that either Nixon or his critics desire increasing the risk of nuclear war. His mining of Haiphong Harbor was criticized for increasing that risk. Whether it did or did not increase the risk is, of course, dependent upon the particular image being employed. The difference between Nixon and his critics may be viewed less as a disagreement about policy objectives and more as one over the appropriate image of reality. The point here is that to analyze the behavior of a foreign policy mechanism it is not enough to simply identify the task environment. The analyst must also consider how the particular task environment will be represented within the mechanism.

One possible way of increasing the ability of the foreign policy mechanism to adapt to its task environment is to change its internal image of its task environment. Oftentimes developing a more appropriate representation of the problem will make the problem much easier to deal with. Consider, the task of multiplying two large numbers. Most of us would find solving (i.e. behaving appropriately) such problems to be very difficult if the numbers were represented as Roman numerals. Simply changing the representation to a more familiar notational scheme makes solving the problem much simpler.

This same problem of internal representation is faced by designers of algorithms by which computers can play chess. How can the task environment of a typical chess game best be represented within a computer? This problem has attracted considerable attention since it has been felt by many that the principles necessary to playing good chess are similiar to those required for dealing with other more general problems such as management and policy planning. A brief look at the approaches used in designing machine chess players should be helpful in clarifying the significance of the internal problem representation.

Shannon (1950) first identified the two approaches chess playing algorithms might take:

1. Scan all possible moves and construct a decision tree of equal length for each move (length here refers to the number of moves into the future the program scans). Then, using some weighting function the possible moves can be evaluated and the best one chosen.
2. Scan only certain moves. Eliminate others through the use of some special rule.

The first approach requires the computer to represent the chess board in all its complexity. Very valuable information is treated the same as less important information. The price of this synoptic approach is that, for a given memory size, the number of moves into the future that can be examined is severely limited. Much memory is wasted looking at trivial information. The second approach trys to avoid this problem. By pre-excluding weak moves a longer future can be considered. Unfortunately, the rule for eliminating bad moves is most difficult to discover.

The problem facing designers of chess playing machines was an interesting one. They had two approaches--one is easily implemented but rather wasteful and the other is very efficient but extremely difficult to implement. Mihail Botvinnik, a Russian grandmaster and electrical engineer, has spent considerable effort in trying to develop an algorithm for chess which is based upon the second principle. Central to Botvinnik's algorithm is the concept of "horizon." At each half-move point the computer generates a mathematical "map" of the chess board. The horizon limits the area of the map scanned by the computer much as natural boundaries limit our horizon. "The horizon is the boundary of the region containing those pieces, and only those pieces, that can take an active role within the given limits of time for movement". . . An attack falling within the horizon is included in the mathematical calculations--otherwise, it is not."

Rather than having the machine calculate all positions and eliminate some very early, Botvinnik has developed a means by which the machine's internal representation immediately eliminates (by not representing it) trivial information. This, of course, should greatly increase the depth to which moves within the horizon may be considered. Thus the way in which the problem is represented internally is important even in dealing with problems in which all information is, at least to some degree, relevant.

A less precise example of this point can be drawn from Ellsberg's (1972) description of U.S. experience in Viet Nam. Let us suppose the task environment here to include (though not exhaustively) the combat areas of Viet Nam together with the goal of "not losing Viet Nam this year." Ellsberg describes the usual Viet Minh and Viet Cong response to increased U.S. military intervention:

> After suffering initial setbacks they would lie low for an extended period, gather data, analyze experience, develop, test, and adapt new strategies, then plan and prepare carefully before launching them (1972:120).

The U.S., however, monitored "enemy" strength through its field commanders who in turn equated frequency of enemy contact with enemy strength. If the enemy is strong, the reasoning went, then it will fight. If it is quiet, then it must be weak. Based on these reports, the tendency was always for the President to view his policy changes as a "success." However, this representation of the problem was not appropriate. Decreased contact did not mean a weakened enemy and, indeed, the periods of greatest crisis came at the times of highest U.S. optimism. One way of "improving" U.S. policy might have been to change the problem representation from one in terms of field commander's reports of enemy strength to one in some other objects. With respect to the artificial system structure, the observation interface needed improvement.

CONCLUSIONS AND IMPLICATIONS

The stated purpose of this paper has been to identify a set of concepts with which to begin to build an "appreciative" theory of foreign policy behavior. More specifically, I have attempted to show how the rather vague notion of "adaptive foreign policy behavior" can be rendered more precise by viewing foreign policy behavior from an artificial systems perspective.

Such a perspective has a number of implications for both theoretical and empirical research on foreign policy behavior. First, it entails the use of a systems vocabulary. This requirement is, however, not very restrictive.

If one adopts the very abstract definition suggested in this paper, then to specify a system is to identify the objects and relations of the "world" being theorized about. Thus as long as one is prepared to be explicit about what it is he is studying, he can use a systems vocabulary.

The second implication of the artificial systems vocabulary is its distinction between the foreign policy generating mechanism (i.e., the inner environment together with goals, interfaces and images) and the outer environment (including, of course, the task environments). The mechanism is posited to behave in such a way as to seek to adapt (achieve goals, solve problems) to its task environments. The internal structure (i.e., the objects and relations) of the foreign policy mechanism becomes very important for a number of reasons.

First, goals can be viewed as constraints upon behavior rather than as precise specifications of required behavior, and the way the mechanism is structured will also severely constrain behavior. Indeed, output behavior was defined as being a function of inputs and internal states. What appears to be goal oriented behavior may sometimes be an artifact of the structuring of the mechanism itself. Conversely, certain objectives may be unattainable unless the mechanism is restructured. As an example, a mechanism whose goal set includes some sort of world disarmament may find that structural constraints on its inspection capabilities (i.e., its observation interface) make such an objective itself infeasible (i.e., this constraint is itself dominated by structural constraints).

Second, the mechanism's internal images of its task environment will often determine its foreign policy behavior. These images form the "perceived

reality" on which policy actions are pretested. A mechanism whose components have very similar images of reality will exhibit greater consistency in its foreign policy over its task environments than will one which is characterized by widely divergent images. Note that images do not include goals except insofar as the image may so severly constrain behavior as to give the behavior the appearance of being directed toward some specified goal.

In terms of a research program, the approach developed here requires that attention be paid not only to the revealed behaviors of nations, but also to the mechanisms which are producing these behaviors and the range of behaviors it is theoretically possible for the mechanism to produce. In addition to descriptive theories which relate behaviors, theories which can account for how the foreign policy mechanism receives, transforms and emits behaviors are required. It is only with such theories that we can begin to assess the capability of various mechanisms to adapt to their task environments.

NOTES

1. See Halperin and Kanter, 1972.
2. For a more complete discussion of this point see Rogowski ( ), or Thorson (1973).
3. Much of the following discussion of artificial systems is adapted from Thorson, 1973.

Military Security Assistance
to
The Persian Gulf States

Conrad C. Gonzales
Project for Theoretical Politics
Ohio State University

August 1973
Project Research Paper No. 19

*The research described in this paper was supported by the Advanced Research Projects Agency Contract No. DAHC 15 73 C 0197.

Best
Available
Copy

MILITARY SECURITY ASSISTANCE TO THE PERSIAN GULF: AN ANALYSIS OF DECISION CRITERIA AND RELATIONSHIPS.

Introduction:

The principal purpose of this paper is to present a brief sketch of factors and constraints which bear upon the formation and execution of American foreign policies toward certain countries of the Middle East. In passing, it will present for consideration certain hypotheses about relationships between and among these factors and constraints.

By "factors" is meant those aggregate and integrated conceptualizations held by authorized governmental decision makers, which result in the articulation of:

1. Specific policy goals and objectives,
2. Specific undertakings or courses of action embarked upon to secure these goals and objectives,
3. specific criteria or decision rules which prescribe the desired limits of permissable substantive action, given certain goals and objectives.

A "factor," therefore, is stipulatively defined as the subjective assessment of a decision maker.

A "constraint," on the other hand, is stipulatively defined as a property of the decision-making or policy implementation structure which limits a particular relationship, or range of relationships between factors or groupings of factors.

Methodology:

The rationale behind such a treatment is based upon the assumption of purposive action on the part of foreign policy makers. While action is presumed to be an outgrowth both of consensus and disensus over maintenance or alteration of status quo, unity and coherence of purpose across levels is not presumed. Although it may be obvious that the extent of consensus and disensus is a matter of degree, it

may not be obvious that the extent of accord manifest at the level of general goal formulation may neither in degree nor in kind be reflected at lower levels of specific policy selection/implementation. Nor is it obvious whether or how vertical as well as horizontal incongruity may impact upon the outcomes of specific undertakings, thus affecting the probability of goal achievement. Stated somewhat differently, there is no assumption in this study of a perfect ends-means relationship between articulated goals and the specific policies or mechanisms settled upon for their attempted achievement. What is suggested, rather than tacitly precluded, at the offset, is the possibility of interaction between differing multi-level conceptualizations,-- an interaction which admittedly may or may not exist, but which, if it does exist, may result in reciprocal goal-means ambiguity, and output attenuation.

A further assumption in this analysis is that "policy" defined in terms of goal-oriented actions is knowable through what the authors of policy say as well as what they do. While there is little question that one relies at his own risk on a policy maker's assurances, given the time honored foreign policy practice of deception, there seemed little reason (until Watergate) to suspect, much less believe, that one major branch of a given government might consciously lie to another,-- particularly when the funding of policy action proposals might be at stake. Thus it seemed reasonable to assume that examination of Congressional testimony of those executives charged with the formulation, implementation, and in certain circumstances, defense of policy, would reveal most accurately the perceptions of "National Interest" which lay behind their expressed desires to undertake certain kinds of specific policy actions. This is not to ignore the possibility that there may be considerable variance between closed door testimony and the public record, but rather to work under the assumption that such variance is a matter of informational degree and detail, and not of inconsistency or contra-

diction.

As a result, what follows is based largely upon public transcripts of hearings conducted during the 1972-1973 time frame, and is offered as an explication of what policy makers defended as the goal of American foreign policy in the Middle East, and the optimum means of achieving it. If one were to summarize these in a few paragraphs, they might read as follows.

Policy Statement:

The United States government seeks to secure in the Persian Gulf sector of the Middle East, a condition of "relative peace" and "status quo stability" free from direct or indirect major power intervention/confrontation, in order to forestall the formulation of multination realignments which might adversely affect the accessibility of oil to American, West European, and non-communist markets.[1]

By "relative peace" is meant the absence of armed conflict in levels sufficient to:

1. "resolve" the Egypt-Israeli conflict on a win-lose absolute basis,[2]
2. or sufficient to permit the outbreak, progressive growth, and spread of insurgency anywhere in the area.[3]

By "status quo stability" is meant:

1. the preservation of existing governmental institutions (as a minimum) and their peaceful transformation along popular participative lines as socio-economic modernization proceeds (as a maximum),
2. the preservation of current levels of political alignment/realignment with Communist/Non-communist nations (as a minimum),
3. the encouragement of perceived desires for socio-economic development.

The primary internal determinant of this regional policy goal is the implicit assessment of U.S. capability and interests which give rise to the so-called "Nixon Doctrine." This has been a recurrent point of reference during hearings. Two aspects of State Department interpretations of this doctrine stand out with reference to the Middle East:

1. a rejection of the self-styled role of global policeman in view of domestic socio-economic resource limitations,
2. Sharper emphasis on the priority of domestic "vital interests" over foreign.[5]

As Assistant Secretary of State for Near Eastern and South Asian Affairs, Joseph Sisco, has observed, the Nixon Doctrine "...has been basically a doctrine of disengagement and engagement on a more selective basis."[6] While asserting that the U.S. stands ready to help those who are willing to help themselves, the doctrine and its subsequent interpretive reiterations also stress reduced involvement, and a distinct preference for material rather than manpower assistance, if the latter is deemed unavoidable.[7]

The primary external determinant has been an anticipated greater dependence on the Middle East as a source of petroleum.[8] Sisco has commented that

> "...the Gulf is an area of strategic importance in itself an important regional waterway, and its importance has increased in recent years economically, and in particular because of its vast petroleum resources..."[9]

> "Obviously, oil is a very, very vital part of this entire area and certainly vital in terms of the economies of our NATO allies and our friends east of Suez..."[10]

What circumscribe and shape U.S. options for goal attainment are the uncertainties associated with:

1. disposition of the Arab-Israeli conflict, in terms of levels of Soviet and/or third country arms assistance,[11]
2. pro-Arab predispositions of certain Riparian states,[12] as well as
3. alleged Chinese Communist material support through Aden for the Dhufar insurrection,[13]
4. Territorial jurisdiction conflicts between Saudi-Arabia, Iran, and certain of the Gulf principalities,[14]
5. Organization of Petroleum Export Countries (OPEC) attempts to renegotiate more favorable revenue sharing proportions with European and American oil companies,[15]
6. potential for indirect channeling of American arms from Military Assistance Program recipient countries to Egypt, or for funding Palestinian Guerillas,[16]
7. potential for use of oil export controls, and threatened expropriation of assets as a bargaining lever on the Arab-Israeli issue,[17]
8. Ability of Iran and Saudi-Arabia to purchase arms for cash elsewhere,[18]
9. terms of third country competition for oil resources.[19]

<u>Necessary Conditions for goal attainment</u>:

The Administration views attainment of these goals as contingent upon achievement of intermediate objectives of:

1. keeping the Arab-Israeli conflict below a threshhold which which would encourage increased Soviet involvement in a runaway arms race, or further polarization of regional political alignments in support of Egypt,[20]
2. finding an indigenous neutral replacement for Britain's former peace-keeping influence "east of Suez," in order to head off expansion of Soviet influence and military presence in the Persian Gulf, and to contain, if not deter the spread of insurgency in the area,[21]

3. preventing the Arab monopoly of Persian Gulf oil from becoming a lever for political blackmail over the status of Israel in the future.[22]

These contingencies are interdependent to the extent that one of the two countries identified by the United States a joint inheritors of the British role, Saudi Arabia, has close economic and cultural ties with Egypt, and to the extent that many of the Riparian enclaves display pro-Arab sympathies.[23]

Aside from obvious direct economic and military assistance to Jordan and Israel, U.S. policy makers show a preference for the following specific major policy actions to achieve these intermediate objectives, or necessary conditions:

1. Encouragement of negotiated settlement of the Arab-Israeli dispute, in accordance with U.N. Resolution 242, or the so-called "Rogers Plan,"[24]
2. Large scale arms sales, economic, and technical assistance to Iran and Saudi-Arabia,[25]
3. maintenance of a token military naval presence in the Persian Gulf,[26]
4. refusal to intervene in disputes between American Oil Companies and OPEC, coupled with a verbal stress on "mutual advantages of avoiding extremes."[27]

Implementation of these policies involves problems peculiar both to the State Department, and to the Department of Defense.

<u>Criteria for policy action</u>:

The principal criteria or decision rules governing the latitude of policy implementing actions have also been derived from Department of Defense and Department of State interpretations of the Nixon Doctrine. These were elucidated most clearly perhaps in Undersecretary of State Curtis Tarr's statement before the Senate

Appropriations Committee:

> "...Instead of claiming a monopoly of initiative in the world at large, the President's policy declares that we must tailor our efforts abroad to the willingness of others to accept a greater share of the responsibility..."[28]

Tarr goes on to say that American National Security interest , i.e., the self-interest of the American people, is only attainable "if we support efforts to foster a measure of order and stability among nations...Through our Security Assistance programs we seek to create and maintain the conditions needed to protect our national interests."[29] In subsequent testimony before the Senate Foreign Relations Committee, Tarr amplified this statement.

> "In determining how our military assistance should be allocated, we also must take into consideration treaty relationships, our military posture abroad, U.S. economic interests, and the extent to which our assistance can provide the foundation for political stability and economic progress in the recipient countries. Thus in responding to your request for a rank ordering of importance, you will appreciate that our priorities with respect to the request for FY 73 funds have been based on the situation in Southeast Asia, the need to maintain a <u>balance of force in the Middle East</u>, and to modernize the forces of countries such as Korea, as the U.S. military sales program is shaped by these same considerations, but in addition Foreign Military Sales (FMS) is used <u>to facilitate the transition from grant recipients to increased reliance on their own resources</u>." (Emphasis added) [30]

What is distinctive about this line of thinking is that there has been a deliberate attempt to institutionalize it both through changes in American military force structure planning and strategy, and through changes in the bureaucratic structure. Defense Secretary Laird stressed that

> "In essence the benefits and aims of security assistance programs correlate directly with the objectives of Total Force Planning as an instrumental component of our Strategy of Realistic Deterrence. It is in this context -- that is, the willingness of our allies to continue improvements in their active and reserve forces, coupled with our efforts to take advantage of our own total force capabilities -- that we should view the merits of our proposed security assistance programs. These assistance programs must allow our allies sufficient time to equip and train adequate deterrent forces. Given sufficient time, our allies can reduce uncertainties as to their capabilities, and simultaneously influence the perception of potential aggressors as to their resolve to use those

capabilities, should deterrence fail.

"Our security assistance programs are designed to help our friends and allies establish these capabilities, to reduce this degree of uncertainty, and thereby enhance prospects for a more stable international environment. The end result of this stabilized international environment is both its contribution to the protection of our own vital national interests, and its contribution to world peace."[31]

These statements have been quoted at length because of the presence and recurrence of a number of phrases and concepts, other than merely "peace, stability, balance, realistic, and National Interest." In Pentagon jargon, "Total Force Planning" has a very specific meaning, and has been shown most recently to involve a domestic restructuring of roles and missions between active duty Federal forces, and Reserve or National Guard units. This has been much more than a paper structural change, and has involved massive transfers of men and materiel from full time to part time involvement. As wave after wave of White House directed force reductions have reduced the Federal establishment, Reserve and National Guard units have been re-equipped and given new roles. Guard and Reserve training has been intensified. Funding responsibilities in Federal and State budgets have shifted. This is perhaps most evident in Continental Air Defense, where nearly 75% of the Air Defense responsibility for the entire United States now rests with units of the Army and Air National Guard.

As perceived by the Department of Defense, Force Structure Planning as instituted by Hitch and Enthoven[32] now involves greater reliance upon the "Combat Readiness" of military resources whose proportionate composition of full and part time participation has changed.[33] This is a major change in operational concept. "Force in being" no longer has the same magnitude or potential. The point is that Secretary Laird's extension of this concept to an integration of allied as well as American capability in the determination of credible basis for a "strategy of Realistic Deterrence" suggests more than a mere intent to help others help themselves. It suggests

an implicit heavy reliance on their ability and willingness to do so.[34]

It's noteworthy also that Secretary Laird used the term "allies." Presumably he refers to nations allied through formal treaties, such as NATO and SEATO. If so, a linkage with Middle Eastern policy becomes evident. If Western Europe is to "pull its weight," its economy must remain economically strong. But Europe's ability to remain economically strong over the next few decades may be a function of access to adequate energy resources such as oil.

Organizational Changes to Maximize Compliance With General Criteria:

Recent events illustrate the extent to which implementation of military assistance aspects of the Nixon Doctrine has involved major formal organizational changes in the Department of State and in the Department of Defense.

During calendar 1971, the Defense Security Assistance Agency (DSAA), headed by a "Deputy Assistant Secretary of Defense (International Security Affairs) for Security Assistance," was created

1. to provide a single point of responsibility within DOD for Military Security Assistance (MSA) programs,
2. to relate the planning for MSA to U.S. Force Planning, and
3. to insure, through coordination with the Department of State (DOS) that security assistance programs are consistent with U.S. Foreign policy.

The DSAA administers the three principal elements of Military Security Assistance:

1. Military Grants, i.e., equipment, services, and training on a "give-away" basis,
2. Military Sales (FMS), i.e., handling negotiations and details,
3. Excess equipment transfers.

The DSAA has been tasked to integrate comprehensive MSA planning with U.S. Force planning. This includes assessment of such items as recipient defense budgets, the mix of U.S. grant, sales, and excess equipment required and provided, third country assistance, and evaluation of the recipient's ability to absorb the operating and maintenance costs of their developing force structures. The emphasis is clearly upon multi-level program management,-- planning, organizing, directing, coordinating, and controlling specific country/region programs which will procure, develop, and maintain an "adequate" self-sustaining force structure in foreign countries, consistent with the Nixon Doctrine's concept of "Realistic Deterrence." The determination of adequacy is a joint endeavor involving the National Security Council, the Treasury Department, DOS, DOD, JCS, and "Country Team" representatives. It attempts ongoing validation of

1. "the relationship of the recipient country's defense capability to U.S. security,
2. the realistic force level which is needed and can be sustained,
3. the kinds and mix of military security assistance that will be required...
4. the scope and phasing of self-sufficiency actions"[35]

This joint effort is handled through the interdepartmental Security Assiatnce Program Review Committee, headed by an Undersecretary of State "Coordinator for Security Assistance," (CSA) a post created in March 1972.[36] It should be noted that this interdepartmental relationship was a subject for discussion du ng hearings.

"Senator Proxmire: ...Who, if anyone, has charge of this overall program...Supposing you disagree on this approach, is this something you have to go to the President to reconcile, there is no final authority in either the Department of Defense or the Department of State?

General Seignious: If the Secretary of Defense and the Secretary of State cannot agree on fundamental policy,

> it can be referred to the National Security Council for determination by the President...The disagreements that require Presidential determination are very, very few, sir. The working relationship between Mr. Tarr's office, the Coordinator for Security Assistance in the Department of State, and the new structure in the Defense Department is excellent..."[37]

In addition to the Security Assistance Program Review Committee (SAPRC), the State Dpeartment organizational structure contains the Office of Munitions Control, and the Office of Military Assistance and Sales, both of which work closely together under the Director of the Bureau of Politico-military Affairs (BPMA) to meet statutory requirements and "executive branch decisions covering the export of strategic materials, munitions, military hardware, and spare parts."[38]

> "Under section 2 of the Foreign Military Sales Act, the Secretary of State is responsible for the 'continuous supervision and general direction of' sales under the act, including but not limited to determining whether there shall be a sale to a country and the amount thereof.
>
> "However, section 42 of the act states that the Secretary of Defense shall have primary responsibility for, among other things, 'the procurement of military equipment in a manner which permits its integration with service program' and 'the movement and delivery of military end items.'"[39]

State Department, through BPMA, therefore exercises ultimate control over the flow of materiel.

The expressed intent to formalize Total Force Programming down to the level of advisory participation in a recipient country's local force structure planning and budgeting, seems in part an attempt to exercise some limiting control (however feeble) over the potential employment of weapons systems. American weapons systems, such as the HAWK surface-to-air missile and the F-4 Phantom, are complex, requiring specialized support equipment for fire control/weapons delivery subsystem maintenance and calibration. A decision on the part of a foreign

country to procure such a systemic family, to some extent ties the buyer to ongoing specialized material support, thus providing some level of ongoing logistic dependence upon the seller. A decision to rely upon a number of foreign suppliers for different systems offsets this dependence, but may come at a cost. One expense is the overhead of maintaining non-standardized support subsystems. Another is the risk of eliciting a response from the American seller of reduced aid funding in non-military sectors. Presumably, this is what DOS and DOD envision. Congressional testimony has, however, indicated the administration's desire to expand the attractiveness of American Foreign Military Sales through credit terms which will make their pricing competitive on the world market.[40] This could have significant implications for sales to Saudi-Arabia and Iran. It should be noted, however, that for the most part, the State Department has emphasized that American Foreign Policy toward the Persian Gulf principalities is aimed at keeping the area free from major power confrontation so that it can pursue local interests. Joseph Sisco comments:

> "...From the point of view of U.S. policy, we believe that two countries in particular have the most direct interest and can make the most positive contribution toward stability in the Persian Gulf, namely Iran and Saudi Arabia. So the kind of policy we are pursuing, Mr. Whalley, is simply this: we are encouraging these two countries to cooperate to the maximum.
>
> Mr. Whalley: This particular area is pretty much able to take care of itself, is that right?
>
> Mr. Sisco: No, I would not put it that way, because while it has very considerable resources, these are very much less developed countries and less developed societies. What we are concerned about, quite frankly, is that a number of these small entities are now expected to stand on their own two feet without the treaty relationships and assistance which came with those treaty relationships, and the protection, if I can put it that way, that came with those treaty relationships from Great Britain in particular. That is why I say one has to rely on these two larger countries..."[41]

In the same set of hearings, however, Secretary Rogers

responded to a query on guidelines for Military Assistance Program eligibility with the following statement:

> "...We have a criteria we apply. The principal one is what do they propose to use the equipment for. Are we satisfied it is for internal security. Or do we think they have something else in mind. It's true you rely to some extent on past relationships...It's true that there is a certain continuity that exists in foreign affairs. As far as the U.S. is concerned, we aren't fixed in our position; we change our policies from time to time."[42]

In view of the volume of transfers to Iran and Saudi-Arabia, it would appear that the above criteria were at least nominally satisfied.

__Structural Constraints__:

If one conceives of MSA as a type of policy action geared to the achievement of specific goals and objectives, then the fact that both the Pentagon planning process and the DOS-DOD bureaucratic structure have been modified to implement execution of the MSA program within the context of military aspects of the Nixon Doctrine suggests a number of things.

First of all, it suggests a potentially problematic role differentiation between the Department of State and the Department of Defense which charges the former with determination of how the MSA program in a given country is to be fitted at any given time into U.S. regional and global policies. DOD, however, tailors the specifics of in-country operations to on-going DOS requirements, at the same time tailoring U.S. Force structures for the expected contribution of the ally. DOD is concerned with the probable effectiveness of joint foreign and domestic military employment. State is concerned with the deterrent credibility index of joint military capability as a policy tool. The longitudinal continuity characteristic of in-country force development signals that fluctuations of policy toward a given country or area in response to external events may impact severely upon programs in progress. The possibility of adverse impact may at best act as a constraint on overall policy flexibility, at worst offsetting both deterrrent credibility and

defense capability by reducing the capability of the "Total Force" structure.

In either case, the success of policy is predicated upon DOD's ability to elicit the desired response. This of itself may be problematic from a strictly technical standpoint. A "slow down" capacity exists. A "speed up" capacity may not. To the extent that DOD is able to respond, no problem will exist. But the potential for chronic frustration is there, which itself may be dysfunctioal in the total force context. Stated differently: while DOS addresses the "whether" questions, DOD addresses the "how" questions. Answers to each involve different kinds of concerns and problems, whose solutions may subtract from each other _in toto_ or in part.[43]

The DOD-DOS modification also suggests that the broadest criteria for determining who gets what by way of military assistance turns upon the estimated potential of the propective recipient to finance and field a defensive force adequate for what in the U.S. view are its own local needs, and directly or indirectly supportive of U.S. policies which are themselves both shaped and circumscribed by the Nixon doctrine.

Factors and Constraints:

On the basis of the foregoing analysis, it is hypothesized that the following major factors shape MSA policy formulation and implementation in the Persian Gulf sector of the Middle East:

1. Internal: U.S. government judgments regarding:

   a. the limits imposed by the Nixon Doctrine on the nature of assistance and its on-going administration,

   b. Current area policy goals, objectives, and actions, in relation to global policies,

   c. extent of the requirement for integrated force structure planning,

   d. domestic energy needs,[44]

   e. Congressional funding support.

2. External: U.S. government judgments regarding:

   a. level of Arab-Israeli hostilities,

   b. level of third country arms assistance to Egypt,

   c. level of externally supported armed insurrection in the Gulf principalities,

   d. level of third country petroleum resource needs,

   e. level of Soviet naval activity in the Persian Gulf and Indian Ocean,

   f. level and nature of local conflict among Gulf principalities, including Saudi-Arabia and Iran,

   g. absorption capacity of recipient nations <u>vis</u> <u>a</u> <u>vis</u> employment of modern armaments,[45]

   h. Regional political alignment and extent of support for Palestinian guerillas.

It is further hypothesized that the following major internal constraints will attentuate or facilitate the successful implementation of MSA policy actions:

1. level of conflicting judgments within the role differentiated structure of executive decision making mechanisms associated with formulation/administration of specific policy actions within the MSA program,

2. level of funding continuity as a function of Congressional support,

3. extent of effective control over "defense systems" disposition in the recipient country.

It should be noted that the above constraints are conceptually limited to properties of the structure of the U.S. decision process. This follows from the decision to limit the focus of this analysis to how U.S. policy makers view the task.

Relationships:

The following propositions reflect the hypothesized relationships among factors, suggested by the foregoing analysis.

1. The degree of regional peace and stability in the Persian Gulf area is viewed a a function of
   a. level of local area conflicts,
   b. level of local area insurgency,
   c. level of Sino-Soviet presence and support for a and b,
   d. the military capacities of Iran and Saudi-Arabia.

2. The extent of the military capacities of Saudi-Arabia and Iran is viewed as a function of
   a. levels of technological absorption capacity,[47]
   b. levels of externally provided armaments.

3. The volume of armaments and technical assistance provided to Iran and Saudi-Arabia are viewed as a function of
   a. U.S. decisions made interdepartmentally in the executive branch related to estimates of all of the above,
   b. consistency with tenets of the Nixon Doctrine,
   c. estimates of third country (ally-non-ally, competitor-non-competitor) need for petroleum resources,
   d. functional integration of U.S. policy toward the Persian Gulf with other regional U.S. policies,
   e. extent of support from Persian Gulf countries for Egypt and/or Palestinian Guerillas,
   f. level of Arab-Israeli conflict,
   g. extent of success of previous policy of military assistance to Iran and Saudi-Arabia,
   h. extent of Congressional concurrence.

4. Extent of Congressional concurrence is viewed as a function of

   a. levels of oil company satisfaction with Persian Gulf policies toward them,

   b. levels of U.S. domestic energy needs,

   c. extent of success of previous military assistance and policies toward the Persian Gulf region,

   d. general level of satisfaction with the administration's performance.

5. Extent of Persian Gulf country support of Egypt and/or Palestinian Guerillas is viewed as a function of

   a. level of Iranian/Saudi-Arabian military economic capability,

   b. level and balance of Arab-Israeli conflict,

6. Level of Arab Israeli conflict is viewed as a function of

   a. Volume of Palestinian Guerilla activity,

   b. Egyptian-Israeli arms balance.

7. Level of Oil Company satisfaction with Persian Gulf policies is viewed as a function of

   a. OPEC negotiations,

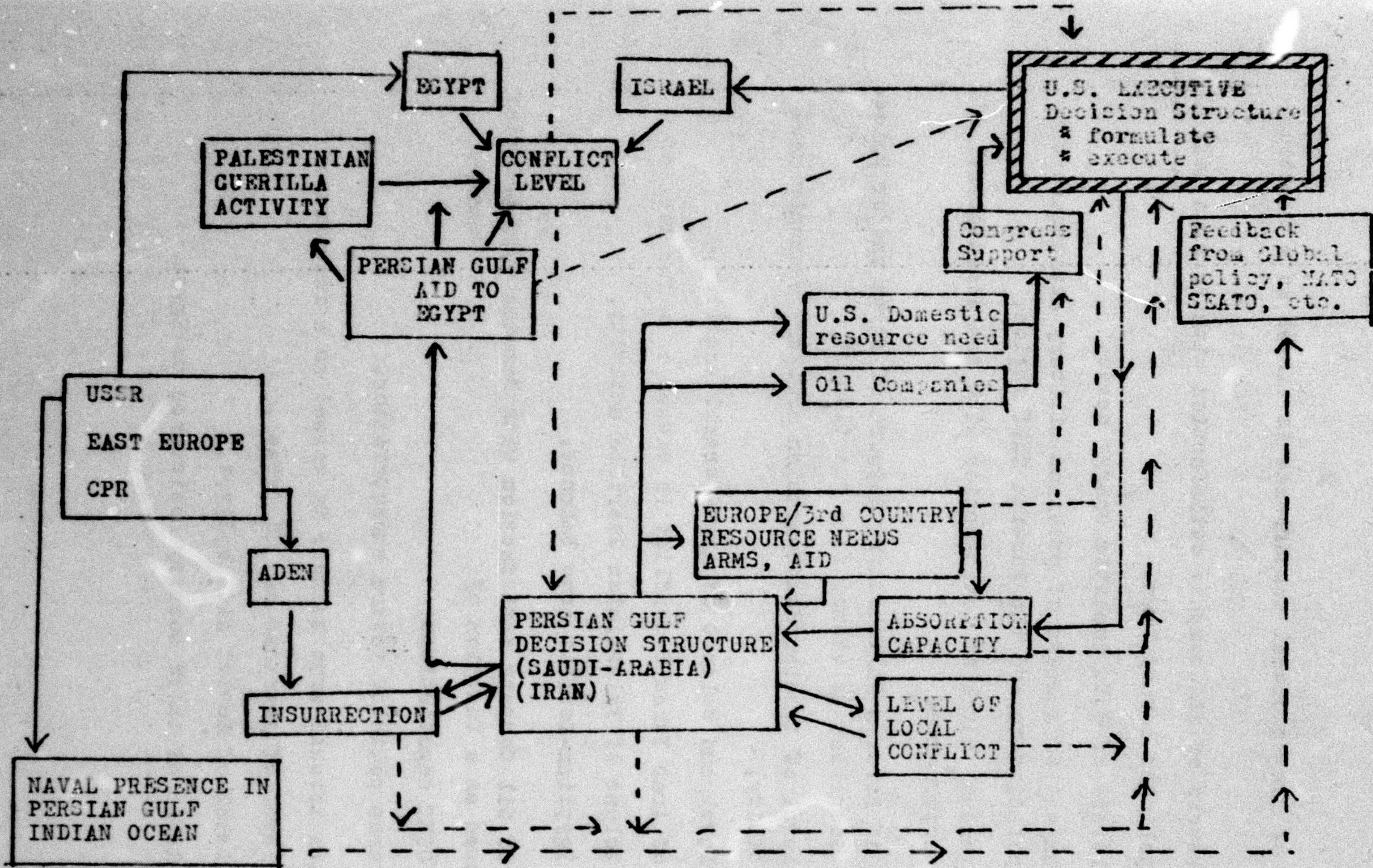
   b. area policies toward expropriation.

8. Egyptian Israeli arms balance is viewed as a function of

   a. level of American aid to Israel,

   b. level of Soviet aid to Egypt,

   c. level of third country assistance to Egypt.



LEGEND: Solid lines: flows of arms, aid, support, positive policy actions
Dotted lines: Information Feedback
Crosshatch: Constraints (dissensus, lack of funds, inability to control)

<u>OIL</u>, <u>ARMS</u>, <u>AND POLITICS IN THE PERSIAN GULF</u>: <u>A RELATIONAL ANALYSIS</u>

It should be noted that the three constraints have been integrated into the above schematic model in different ways. Congressional funding support and control of recipient use of resources are treated as variables,-- the latter as a function of direct feedback from recipient nation policy actions. Bureaucratic dissensus is treated as a single function, or "efficiency ratio."

The principal dynamic patterns which the schematic reflects suggest that:

1. An Arab-Israeli arms imbalance may raise the level of conflict. To the extent that it does, pressure will be placed on Saudi-Arabia to assist covertly or overtly.
2. If Saudi-Arabia does assist, U.S. security assistance may or may not be cut off depending upon the U.S. requirement for oil. Sisco was confronted with the question whether the U.S. might ever be faced with a situation wherein it could be blackmailed over oil. His response was that he felt certain that the Arab nations of the Gulf considered their need for technical and marketing knowledge a more pressing requirement than settlement of the Israeli question, and considered cooperation on matters of oil essential to this access. His built in assumption is that awareness of commonality of profit interests would override irresponsible use of oil as a political weapon.[48]
3. The limiting factor on Saudi-Arabia is absorption capacity, but only in terms of improving its military establishment and general level of development. The potential for local area conflict between Saudi-Arabia and Iran, may deter Saudi covert assistance to Egypt, unless cultural sympathies cause oil to be used as a lever to induce U.S. pressures on Iran to cease and desist. This might involve an aid "slow down" the effectiveness of which would turn on Iran's ability to receive aid elsewhere, or real need of it, for that matter.

4. Aden-based covert support of insurgency would lessen the probability of extensive covert or overt active support of Egypt and increase dependence upon U.S. military assistance in the Gulf area.

5. Third country activity may have a profound impact upon the policies of the Persian Gulf countries, vis a vis their need for markets and armaments, and their policies toward Egypt, on a "quid pro quo" basis.

Conclusion:

This brief analysis of conceptual relationships should be considered no more than an exploratory "ranging shot" at delineating the way U.S. national objectives are specified vis a vis the Persian Gulf, on the part of the Departments of State and Defense. It is couched in an American value perspective, and based entirely on what Departmental representatives have said in unclassified Congressional testimony. It employs a rather simple-minded methodology of "eyeball scan" rather than more sophisticated content analysis and propositional inventory. A more scientifically based approach might yield more reliable results. As such, the factors, constraints, and relationships have been derived, and quasi-translated into potentially quantifiable terms. Obviously, the translation needs much refinement. Single or composite indicators need to be developed which will reflect degrees and/or rates of change in the variables. Given the substantive nature of the variables, I feel that this is within the range of possibility, at least to an ordinal level of measurement.

As far as substance is concerned, there are a number of spinoff issues which might bear fruitfull examination on their own merit. The first of these relates to the style and content of Committee testimony:

1. The more powerful the committee, the more nebulous and general the answers and arguments, even in response to specific questions. Curtis Tarr's 1972 performance before the Senate Appropriations Committee differed considerably from his performance before the Senate Foreign Relations Committee in 1973 vis a vis the

level of glittering generality. In 1973, this seemed inversely related to the precision of Senator Fulbright's questions. Joseph Sisco's testimony to the House Foreign Affairs Committee's Near Eastern Affairs Subcommittee was much more rich in detail than his deliveries before the major Senate and House Units. This may in part be attributable to the scope of the hearing topic, i.e., foreign aid in general, rather than specific regional operations. But it may be a function of other significant perceptions as well.

2. Military testimony for the most part is non-policy evaluative, dealing exclusively with estimates of efficiency and effectiveness of specific actions embarked upon in support of specific policy programs. Such misgivings as may be voiced are generally linked with problems generated by the uncertainties of annual funding, and the requirements of total force planning.

This area, the interface between Congressional support, DOS policy objectives, and DOD operations in support of these objectives warrants further study because of its longitudinal impact upon MSA actions, and therefore the likelihood of goal attainment. There are conflicting and overlapping interests here. The net impact of the discord might be worth investigation, given the tendency toward increased lateral and vertical interdependence.

In a more abstract context, the schematic relationships depicted above, if in fact they do obtain, may be considered one subsystemic component of a larger conceptual system depicting a sixfold set of relationships governing the dynamics of U.S. Foreign Assistance decisions:

1. An actor
2. A recipient
3. A competitor
4. Third Partiès whose action/inaction makes a difference
5. A fluctuating level of external conflict
6. A set of value criteria for determining the actor's action *vis a vis* a given policy.

As such, it might be useful as a heuristic device for the generation of hypotheses about systemic behavior. The conditions necessary to raise the model to this conceptual level involve validation or assumption

1. that the dynamics described in the model of the subsystem can be applied universally to U.S. Foreign Aid operations,
2. that the dynamics described in the model of the subsystem suggest a category or class of behaviors *vis a vis* a class of policy actions by a certain kind of government with a given configuration of resources, and a given perception of role, in the context of a given perception of the global political system.

This might prove a springboard for fruitfull comparative examination of how differently organized national actors might pursue similar actions.

Footnotes:

[1]"U.S. Interests in and Policy Toward the Persian Gulf," Hearings Before the Subcommittee of the Near East of the Committee on Foreign Affairs, House of Representatives, 92nd Congress, 2nd Session (Washington: Government Printing Office, 1972), pp. 80-85, 93-95. Hereafter, this document will be referred to as "Persian Gulf Hearings."

[2]"Foreign Assistance and Related Programs Appropriation, Fiscal Year 1973," Hearings Before the Committee on Appropriations, U.S. Senate, 92nd Congress, 2nd Session (Washington: Government Printing Office, 1972), pp. 248-249. Hereafter, this document will be referred to as "FY 73 Appropriations Hearings."

[3]"Persian Gulf Hearings," *Op. Cit.*

[4]*Ibid.*, p. 80.

[5]"FY 73 Appropriations Hearings," *Op. Cit.*, pp. 567-568.

[6]"Persian Gulf Hearings," *Op. Cit.*, p. 95.

[7]Richard M. Nixon, *U.S. Foreign Policy for the 1970s: Shaping A Durable Peace*, A Report to the Congress (Washington: Government Printing Office, 1973), pp. 190-191.

[8]"Persian Gulf Hearings," *Op. Cit.*, pp. 93-97.

[9]*Ibid.*, p. 76.

[10]*Ibid.*, p. 80. Joseph Sisco subsequently identified Saudi Arabia as the anticipated source of oil against future U.S. requirements. In a direct reference to Saudi Arabia, he comments,"...I think basically in this country we have all of the resources that we are ever going to need for our energy in the long run. And I stress 'the long run.'" cf. "Department of State Authorization for FY 1974," Hearings Before the Subcommittee on State Department Organization and Foreign Operations of the Committee on Foreign Affairs, House of Representatives, 93rd Congress, 1st Session (Washington: Government Printing Office, 1973), p. 24. Hereafter, "DSA 74."

[11]"FY 73 Appropriations Hearings," *Op. Cit.*, pp. 248-250.

[12]"Persian Gulf Hearings," *Op. Cit.*, p. 90.

[13]*Ibid.*, p. 106.

[14] *Ibid.*, pp. 15 and 86.

[15] *Ibid.*, pp. 33-74, and 96-98.

[16] "FY 73 Appropriations Hearings," *Op. Cit.*, p. 944.

[17] "Persian Gulf Hearings," *Op. Cit.*, p. 111.

[18] *Ibid.*, pp. 14-16.

[19] *Ibid.*, p. 94.

[20] *Ibid.*, p. 95.

[21] *Ibid.*, pp. 95-97.

[22] *Ibid.*, p. 101.

[23] *Ibid.*, pp. 14, 15, 26, and 27.

[24] "Foreign Assistance Act of 1972," Hearings Before the Committee on Foreign Affairs, House of Representatives, 92nd Congress, 2nd Session, Part 1 (Washington: Government Printing Office, 1972) pp. 36-37. Hereafter, this document will be referred to as "FAA 72 Hearings."

[25] "Persian Gulf Hearings," *Op. Cit.*, p. 15.

[26] *Ibid.*, pp. 9-31 and 95. See also "Executive Agreements With Portugal and Bahrain," Hearings before the Committee on Foreign Relations, United States Senate, 92nd Congress, 2nd Session, on S. Res 214 (Washington: Governemnt Printing Office, 1972).

[27] *Ibid.*, pp. 96-98. See also "Foreign Policy Implications Of The Energy Crisis," Hearings Before the Subcommittee on Foreign Economic Policy of the Committee on Foreign Affairs, House of Repre-sentatives, 92nd Congress, 2nd Session, (Washington: Government Printing Office, 1972), hereafter called "Energy Crisis Hearings."

[28] "FY 73 Appropriations Hearings," *Op. Cit.*, p. 568.

[29] *Ibid.*

[30]"Foreign Military Sales and Assistance Act," Hearings Before the Committee on Foreign Relations of the United States Senate, 93rd Congress, 1st Session, (Washington: Government Printing Office, 1973), hereafter called "FMS Act Hearings."

[31]"FY 73 Hearings," Op. Cit., p. 830.

[32]Charles J. Hitch and Roland N. McKean, The Economics of Defense in the Nuclear Age (New York: Atheneum, 1965).

[33]See also Nixon, Op. Cit., pp. 178-193.

[34]Ibid., p. 189.

[35]"FY 73 Hearings," Op. Cit., pp. 916-918.

[36]Ibid., p. 566.

[37]Ibid., p. 922. This may or may not be the case. See Mr. Tarr's responses in "DSA 74," Op. Cit., pp. 10-11; also Congressional Quarterly Weekly, 28 April 1973, p. 1045, which alleges that DOD recently tried to get control away from DOS.

[38]Ibid., p. 200.

[39]Ibid., p. 201.

[40]See Mr. Tarr's statement in "FMS Act Hearings," Op. Cit., p. 4. "... We can easily reduce credit sales by telling our friends that we don't have funds available. This usually encourages the leaders of these nations to purchase military equipment provided by another nation...We would prefer to increase sales while at the same time reducing our military assistance grants..."

[41]"FAA 72 Hearings," Op. Cit., p. 94.

[42]Ibid., p. 16.

[43]"FY 73 Hearings," Op. Cit., pp. 831, 932-956. It's interesting to note the Lt. General Seignious's successor, Vice Admiral Ray Peet elected to soften the funding discontinuity argument, but not abandon it in his testimony before the Fulbright Committee (FMS Act Hearings, Op. Cit.).

[44]See footnote 10 above.

[45]"Persian Gulf Hearings," *Op. Cit.*, pp. 102-106. This has not been dwelt upon extensively in the hearings, other than in the context of the appropriateness of MSA materiel assistance. It seems relevant, however, to any assessment of what one would do with expropriated resources, or a complex mix of sophisticated weaponry. The value of the factor on local recipient foreign policy must be assessed from other sources, particularly in view of an *a priori* assumption of disparity between Iran and Saudi-Arabia.

[46]For purposes of this study, "Palestinian Guerilla Activity" is treated as and attributed to "Egypt."

[47]In interpreting this, one must furnish his own value, since one could not be directly derived from testimony. See footnote 45 above.

[48]See footnotes 27 and 44 above.

MILITARY SECURITY ASSISTANCE
TO THE PERSIAN GULF STATES

(Appendix 1)

Conrad C. Gonzales

APPENDIX 1

This appendix outlines one approach at transforming the preceding conceptual factors and relationships into a decision simulation network which will "control" the flow of military assistance to a would-be Persian Gulf recipient. As such, it is an attempt to "model" the dynamic interrelationships among DOS, DOD, and Congressional concerns made explicit in the hearings.

These concerns have been categorized at the first level according to an "office of prime responsibility" conceptual design consideration, which calls for three separate networks according to role. The Department of State network reflects its role as policy action "Originator." The Department of Defense's role is as policy action "executor." The role of Congress is that of "Funding source and Critic." The output of the DOD and Congressional networks is linked to the DOS network as one of a series of essential concerns, all of which have to be satisfied for military assistance to be initiated or sustained.

Within each of the three networks, a series of substantive essential concerns have been stipulated. Joint concerns appear in more than one network, in order to display the effects of differing perspectives vis a vis the same concern. At this second level of OPR concerns, there has been a crude effort to specify concrete conditions under which military assistance will be granted or denied. "Concerns" are treated as major criteria, whose satisfaction requires hard-evidence satisfaction of sub-criteria, or "conditions." The "conditions" may be simple or complex to be sufficent to affirm a concern. Some concerns consist of arrays of mutually exclusive conditions, any one of which, in being affirmed, is sufficient to affirm the concern. "Unknowns" will neither affirm a condition, nor negate the affirmation of another condition within a concern, as long as that other condition is sufficient of itself. Both the major criteria (concerns) and their component subcriteria (conditions) have been specified in a manner which calls for the explicit presence or absence of a specific behavioral property in the external environment, for its affirmation or denial.

In addition, subcriterial conditions have been weighted, in the sense that they have been assigned an index of relative importance, or "priority code," based upon their immediately apparent relevance to the three-fold rank ordering of National Goals elucidated in Curtis Tarr's testimony.[1] Tarr, emphasized that American National Interests took precedence over all International concerns, and that among International American Interests, responsibilities to allies constituted the next order of business. Finally, he placed the affairs of non-allied nations, and the rest of the world, as a tertiary level concern. This suggests that the preservation or enhancement of American Society, with its political, social, economic, and cultural institutions and values, and those "conditions" most directly relatable to them are priority one considerations. Those conditions most directly relatable to the welfare of allies and alliances are priority two considerations. Those conditions most directly relatable to neither of these are priority three considerations. The same conceptual ordering has been employed in weighting the "conditions" specified in the three networks.

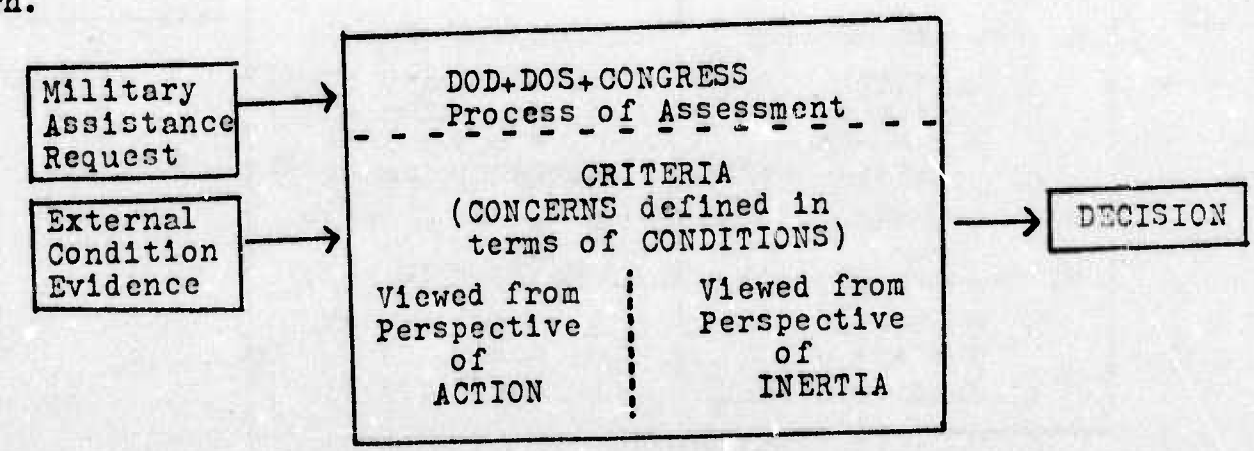
It must be emphasized that nowhere in the testimony could there be found concrete rank orderings of "concerns" or "conditions." As a result, their weighting had to be accomplished on the basis of "face value," or direct obvious relationships to one of the more general three fold rankings. Subcriteria, or concrete "conditions," were assigned "priorities" of one, two, or three, on this basis. What emerged from this preliminary approach was the notion that each essential concern in a network could have a range of priority values, depending upon the value of the condition which affirmed it. This permitted some to override others under differing objective "conditions." The specific value of a concern depended upon the value of the condition which affected it. This allowed Tarr's basic hierarchy of abstract values to remain constant while essential concerns could take on different degrees of comparative importance under differing conditions. Thus, the resultant decision network could cope with environmental fluctuation and "logically" resolve : internal "action/inertia" criterial conflict through suboptimization.

What constitutes "action" and "inertia" requires explanation. Both terms are stipulatively defined in this study. "Action"

simply means the granting of aid. "Inertia" simply means the withholding of aid. Both are distinct perspectives for addressing "conditions," and relating them to concerns. While the substantive context of concerns and their supporting conditions has its roots in the testimony, their formulation in the decision networks is based upon a simplified conceptualization of decision making. They have been stated in a manner which allows one to address the known consequences both of action and of a failure to act, with respect to the same objective condition. That this actually takes place is an assumption. Nevertheless, it was necessary to build such a feature into the networks in order to sensitize them to both aspects of decision. As it turns out, the automatic responsiveness of the control network to internal conflict and external environmental change hinges upon this capacity. A scenario example of how this works is included later in the text.

In summary, then,

1. The aid request comes out of the environment, as do the inputs which affirm or negate the conditions associated with each concern.



2. The negation or affirmation of a condition leads to the negation or affirmation of its associated concern.

3. Affirmation of all "action" concerns results in an interim decision to provide the aid.

4. Negation of <u>one</u> action concern results in an interim decision NOT to provide the aid.
5. Interim "denial" decisions (not to provide aid) are reviewed against "Inertia" criteria.
6. Affirmation of a <u>single</u> inertia concern will reverse an action based interim denial decision IF AND ONLY IF the inertia concern is of higher priority.
7. Priority one overrides priorities two and three; priority two overrides priority three.
8. The inputs from the separate Congressional and DOD networks are integrated into the DOS network as special concerns. Functionally they behave as any other essential concern, and can negate or override or support an interim decision.

DEPARTMENT OF STATE NETWORK

Input	Action Concerns	Inertia Concerns	Input
From Congressional Network →	1. Concern (P=1)	1. Concern (P=1)	← From Congressional Network
	+		
From DOD Network →	2. Concern (P=1-3)	2. Concern (P=1-3)	← From DOD Network
	+		
	3. Concern (P=1-3)	3. Concern (P=1-3)	
	a. Condition (P=1)	a. Condition (P=3)	
	b. Condition (P=3)	b. Condition (P=2)	
	* * * * *	* * * * *	
	n. Condition (P=2)	n. Condition (P=1)	
	* * * * *	* * * * *	
	+		
	N. Concern (P=1-3)	N. Concern (P=1-3)	
	a. Condition (P=2)	a. Condition (P=1)	
	* * * * *	* * * * *	
	n. Condition (P=3)	n. Condition (P=1)	

Where "P" equals priority. Note that the inertia priority value of the same condition may differ from the action priority value.

9. If an override results, the interim denial is reversed and aid will be granted. National Security Council will be advised.
10. If a deadlock results over priority three differences, the denial decision will stand.
11. If a dealock results over priority two or priority one differences, the decision will be deferred, and the matter will be

referred to the National Security Council for major policy priority reconciliation.

The Congressional and DOD networks are still on the drawing board. The action-inertia network for the Department of State is shown below. Note that it incorporates the inputs from Congress and DOD:

<u>DEPARTMENT OF STATE NETWORK</u>: <u>ACTION CRITERIA CONCERNS AND CONDITIONS</u>:

"ASSUMING THE WOULD-BE RECIPIENT REQUESTS IT, DOS AS POLICY ORIGINATOR WILL INITIATE OR SUSTAIN MILITARY ASSISTANCE IF IT PERCEIVES THAT:"

1. CONCERN: Congress acquiesces. (Linkage with Congressional Net) (P=1) Sufficient to kill; necessary to pass.
2. CONCERN: DOD says it is workable. (Linkage with DOD Net) (P=1-3) Necessary.
3. CONCERN: Military aid is required? (P=3) Necessary
   (a) Yes, if insurgency is present, OR (P=3; sufficient)
   (b) Yes, if other external threat which could be thwarted by stronger indigenous military establishment is present. (P=3; sufficient)
4. CONCERN: It's consistent with the "Nixon Doctrine" (P=2; Necessary)
   (a) Yes, if it won't precipitate a major power confrontation, AND (P=2; necessary)
   (b) it involves only materiel/training support, AND (P=3; necessary)
   (c) it <u>does not conflict with</u> U.S. "self-help" alliance policy toward NATO (P=2; necessary; a+b+c=sufficient)

   OR

   (d) Yes, if it won't precipitate a major power confrontation, AND (P=2; necessary)
   (e) it involves only materiel/training support, AND (P=3; necessary)
   (f) it <u>supports</u> U.S. "self-help" policy toward NATO insofar as (P=2; necessary) (d+e+f= sufficient)
      (1) Yes, if the European economy requires oil, AND (P=2; N)
      (2) the European NATO contribution turns on economy. (P=2; N)
      (1+2= Sufficient for f; a+b+c, or d+e+f = sufficient for 4)

5. CONCERN: It doesn't conflict with other U.S. foreign policies in the region? (P=3; N)

(a) Yes, if recipient is not in conflict with other states in the Persian Gulf region similarly supported by the U.S., AND (P=3;N)

(b) if recipient does not materially support Egypt/Palestinian Guerillas (P=3;N) (a+b=S)

(1) if overt monetary, materiel. manpower resource assistanee is in fact denied, AND (P=3,N)

(2) if covert monetary, materiel, manpower resource assistance is provided in volume insufficient to affect level of Arab-Israeli hostilities. (P=3;N) (1+2=sufficient for b)

OR

(c) Yes, if recipient is in conflict with other states in the Persian Gulf region similarly supported by the U.S., AND (P=3;N)

(d) U.S. Military assistance will reduce the conflict, AND (P=3;N)

(e) if recipient does not materially support Egypt/Palestinian Guerillas (P=3;N) (c+d+e=S)

(1) if overt monetary, materiel, manpower resouree assistance is in fact denied, AND (P=3,N)

(2) if covert monetary, materiel, manpower resource assistance is provided in volume insufficient to affect level of Arab-Israeli hostilities. (P=3;N) (1+2=Sufficient for e)

(a+b, or c+d+e = sufficient for 5)

6. CONCERN: If alternative (third country) military aid sources are (P=1-3;N)

(a) not available (P=2;S)

(1) Yes, if reeipient can't pay, OR (P=2;S)

(2) Yes, if no one will sell to recipient. (P=2;S)

OR

(b) undesirable from U.S. standpoint (P=1-3;S)

(1) If expenditure is counterproductive to recipient's fiseal policy, OR (P=3;S)

(2) Yes, if it will eause discord in region, OR (P=3;S)

(3) Yes, if it would reduce U.S. ability to influenee (P=3, S)

a. reeipient's foreign policy toward U.S. and region, OR (P=3,S)

b. recipient's oil poliey toward U.S., OR (P=1;S)

c. Alternate source's foreign policy toward U.S. (P=3;S)

(4) Yes, if alternate source is hostile toward U.S. (P=1;S)

7. CONCERN: If recipient's current policies have been at least non-disruptive (if not supportive) of current U.S. policies (P=1-3N)

   (a) Yes, if availability of regional oil resources to U.S. buyers is not thereby endangered, OR (P=1;S)

   (b) Yes, if availability of recipient's oil resources to U.S. buyers is assured, OR (P=1;S)

   (c) Yes, if U.S. oil companies are satisfied with recipient's treatment, either through (P=3;S)

      (1) acceptable outcomes of OPEC negotiations, OR (P=3;S)

      (2) acceptable remuneration for expropriated assets are received, either (P=3,S)

         a. from recipient country, OR (P=3,S)

         b. from U.S. Governemnt guarantees (P=3,S)

INERTIA CRITERIA CONCERNS AND CONDITIONS:

"ASSUMING THE WOULD-BE RECIPIENT REQUESTS IT, DOS AS POLICY ORIGINATOR MAY REVERSE AN INTERIM DENIAL OF MILITARY ASSISTANCE IF IT PERCEIVES THAT A PRIORITY CONCERN BELOW EXCEEDS THAT OF THE DENIAL CONCERN."

1. CONCERN: Congress acquiesces. (Linkage with Congressional Net) (P=1; Sufficient to kill; necessary to pass)

2. CONCERN: DOD says it is workable (Linkage with DOD Net) (P=1-3)

3. CONCERN: Military aid is required, (P=3,S)

   (a) if failure to give aid will aggravate the insurgency present, OR (P=3;S)

   (b) if failure to give aid will increase the presence of external threats which could be thwarted by a stronger indigenous military establishment. (P=3;S)

4. CONCERN: It's consistent with the Nixon doctrine, (P=2-3;S)

   (a) if failure to give aid will precipitate a major power confrontation, OR (P=3;S)

   (b) if a failure to give aid will call for troop as well as materiel/training support, OR (P=3;S)

   (c) if a failure to give aid conflicts with U.S. "self-help" alliance policy toward NATO (P=2;S)

      (1) If it will inhibit Europe's access to oil, AND (P=2;N)

      (2) If European economic basis for its NATO contribution is based on oil (P=2;N) (1+2=Sufficient for C)

5. CONCERN: It doesn't conflict with other U.S. foreign policies in the region (P=3;S)

   (a) if a failure to give aid will precipitate conflict between

the recipient and other states in the region similarly supported by the U.S., OR (P=3;S)

(b) if a failure to give aid increases already existing conflict between the recipient and other states similarly supported by the U.S. in the region, OR (P=3;S)

(c) if a failure to give aid will cause the recipient to materially support Egypt/Palestinian Guerillas, (P=3;S)

(1) by precipitating overt monetary, materiel, manpower, resource assistance from the recipient, OR (P=3;S)

(2) by increasing the volume of covert monetary, materiel, manpower resource assistance beyond a level sufficient to affect the intensity of Arab-Israeli hostilities. (P=3;S) (1 or 2 = Sufficient for c)

6. CONCERN: If alternative (Third country) military aid sources are not available or undesirable from U.S. standpoint (P=1-3;S)

(a) Yes, if failure to give aid results in overtures to third country

(1) whose required payments decrease funds available for socio-economic development, OR (P=3;S)

(2) whose ties to the recipient are perceived as discordant in the region, (P=3;S)

OR

(b) Yes, if failure to give aid results in third country reduction of U.S. ability to influence

(1) recipient's foreign policy toward U.S. and region, OR (P=3;S)

(2) recipient's oil policy toward U.S., OR (P=1-3;S)

(3) third country foreign policy toward U.S. (P=3;S)

OR

(c) Yes, if third country is hostile to U.S. (P=1;S)

7. CONCERN: If recipient's current policies have been at least non-disruptive (if not supportive) of current U.S. policies

(a) if failure to give aid threatens availability of area oil resources to U.S., OR (P=1;S)

(b) if failure to give aid threatens availability of recipient's oil resources to U.S., OR (P=1;S)

(c) if a failure to give aid causes U.S. Oil Company dissatisfaction

(1) if it worsens outcomes of OPEC negotiations, OR (P=1-3;S)

(2) if it threatens acceptable remuneration for expropriated assets, (P=1;S)

a. from host country, OR (P=3;S)

b. from U.S. Government guarantees. (P=1;S)

AN EXAMPLE OF HOW THE NETWORKS OPERATE:

At T_0, the environment yields a request for military assistance from a wealthy Persian Gulf country. Congress acquiesces, and DOD says it is workable. All other action concerns are affirmed in virtue of one or more of their specified sufficient conditions having been met. An affirmative interim aid decision results. No inertia review is initiated since the interim decision is affirmative. Military assistance begins to flow.

At T_1, the American Embassy in the recipient country reports increased contacts between known agents of the Palestinian Guerillas and members of the recipient'country's foreign ministry. CIA reports conclusion of a funding agreement. American Embassy in Israel reports no significant alteration of Arab-Israeli hostiliies. The assistance decision is reassessed in light of the changed environment. The action criteria essential concern for "conflict with other regional U.S. policies" remains unchanged since the level of guerilla support is "not sufficient" to alter Arab-Israeli hostilities.

At T_2, Arab terrorist activity increases in frequency, triggering Israeli commando raid responses. CIA confirms that payments for guerilla arms purchases in Czechoslovakia are being made out of feeder accounts in Switzerland, replenished by recipient country funds. The assistance decision is reassessed in light of the changed environment. The action criteria concern for "conflict with other U.S. regional policies" is no longer met. An interim denial decision results, which activates a "review" against inertia criteria. Since the recipient's behavior has provided no hard evidence to warrant a change in the original assessment of the inertia criteria, the "denial" decision stands. Diplomatic discussions with the recipient fail to alter the recipient's behavior toward guerillas. The military assistance stops.

At T_3, the recipient requests that the U.S. reconsider its action, and alludes to the possibility of more favorable oil concessions to who ever will help it resolve its internal security

needs. At the same time, it advises U.S. oil companies that it desires new negotiations to adjust royalty rates in view of fluctuations of the U.S. dollar value. U.S. Embassy Moscow reports visit by recipient country's defense minister. CIA Moscow station reports negotiations underway involving port facilities on Persian Gulf. U.S. Embassy in recipient country reports arrival of Soviet Geological Survey Team including naval officers formerly assigned to submarine service. CIA reports no change in funding to Palestinian Guerillas. Arab-Israeli hostilities remain at increased level.

The assistance denial decision is reassessed in light of the changed environment. Since the guerillas are still being aided "significantly," negation of the priority three action condition and concern sustains an interim decision of denial. A review against the inertia criteria reveals that the concern over aid from this particular/alternate source is now affirmed at a priority one level. The concern with the disruptive effect of the recipient's action upon U.S. policies in terms of oil is also affirmed at a priority one level. The oil action-affected conditions under both concerns. The priority one inertia concern over the consequences of a failure to act, overrides the priority three action concern, and the final decision is to resume military asistance. Since an overide was involved, the National Security Council is advised. The override cancels the negative signal from the action concern, and the decision network now recognizes the increased level of aid to the Palestinian Guerillas from the recipient country as below the threshhold of significance.

LIMITATIONS:

The most obvious drawback to the model is that it provides no "increase/decrease" option on aid. This is in part a property of the design. "Mix" and "Volume" of military asistance has tentatively been relegated to the DOD network, since logically it is primarily dependent upon technical needs. It's not clear from the hearings what the precise impact of purely political (DOS) considerations are upon mix and volume. In any case, the "conditions and concerns" affecting mix and volume have not yet been worked out in detail. They are presently addressed in the DOD net within the conceptual

context of the defensive character of the indigenous force.

A second drawback to the model is its narrow range of concern, i.e., starting and stopping military assistance, which in a sense over-emphasizes the implication that the only policy response to a priority one "threat" is through the media of military assistance related policy action. Obviously, it's not. But it can be, and such a limitation is built into the model.

A third drawback is the heterogeneous character of conditions and concerns, which had to be "layed out" and connected artificially. They are discrete products of the hearings, and defied initial scaling, chiefly because there was initially no clear picture of the orientation of the scaling axis, or the range to be covered. A theoretic framework had to be hypothesized in which conditions and concerns could be placed in proper relationship. Whether the resultant relationship is, or is not, proper is a problem stillto be addressed. The tentative assumption has been made that it does, inasmuch as it "hangs together" conceptually vis a vis other DOS and Congressional concerns, yet still remains fairly close to its empirical referrent, the substantive content of the hearings.

The problem thus became one of aligning constructs, and finding empirical indicators for ranges of value within them. This involved analytical separation of "concerns" and specification within "concerns" according to "conditions," or peculiarities of behavior. Certain "conditions" obviously were related to certain concerns, but not necessarily to each other. Some are mutually exclusive. Others are complex or contingent compositles. Still others show up in more than one concern or network. Some suggest scalable properties whose values may be predicated on other values in the environment to which the decision network is relatively insensitive.

For example, except for override conditions, determination of the threshhold for the "sufficient to alter the level of Arab-Israeli hostilities" property of recipient aid to Palestinian

guerillas, require recognition of an alteration in level of Arab-Israeli hostilities before it can be addressed. Similarly, a simplifiying assumption has been made that access to oil is a first priority concern. But here time may make a difference. If the proportionate dependency on a particular country increases as domestic oil needs increase, oil company interests (also first priority by definition, according to Tarr's rank ordering) may at some point have to be sacrificed, or subsidized. The networks make no provision for this, or for recognition of that point beyond a priority one deadlock.

A fourth drawback is the judgmental basis of "sufficiency" built into the network design. Why do all action "concerns" have to be satisfied for aid to flow? The basis for this is <u>inference</u> from the testimony, i.e., that a failure on any "concern" issue is sufficient to deny aid ALL OTHER THINGS BEING EQUAL, INCLUDING TESTIMONIAL EXPLICATIONS OF CURRENT U.S. POLICY AS A GUIDE FOR ACTION. All other things are rarely equal. The environment constitutes a part of them, and the environment constantly changes. One way to take into account the impact of environmental change is to address the impact of inertia <u>vis a vis</u> a given condition. To build this in, required a transformation of the action "conditions" into forms which would allow "Concerns" to be affirmed on the basis of hard behavioral evidence, yet retain the original conceptual substance of both concerns and conditions. What resulted was a kind of "consequence ranging" of action and inertia <u>vis a vis</u> the condition, with the range limitation those points where a policy-action change was <u>clearly</u> indicated. This does <u>not</u> address the exact location of threshholds. Yet it may be a start, provided that the relationships are not merely a result of unconscious design bias.

Although the DOD and Congressional networks are by no means finished, or even well under way, some preliminary conceptual sketchs have been attached below. Am toying with the notion that the DOS network is sufficiently refined verbally to allow an experimental translation into computer language, despite the fact that approximately three dozen separate yes/no statements about an "event" are required as entering arguments to activate it. It might be

interesting to set it up as a simulation to see if it does in fact behave as a decision making network in the way that the scenario suggests.

---

[1]FY 73 Appropriations Hearings, Op. Cit., pp. 568-569.

THE FOLLOWING NETWORK STATES RESULT FROM THE DATA PROVIDED IN THE EXAMPLE, AND MAY BE USED IN CONJUNCTION WITH THE ACTION-INERTIA CRITERIA LISTINGS TO REPLICATE THE RESULTS OF THE SCENARIO. (Y=Affirmation, N= Positive denial based on evidence, N-UNK =denial by default, or lack of positive content basis for an assessment)

At T_o and at T_1:

ACTION

1.Y
2.Y
3.Y
  (a)Y
  (b)N
4.Y
  (a)Y
  (b)Y
  (c)Y
  (d)Y
  (e)Y
  (f)N-UNK
    (1)N-UNK
    (2)N-UNK
5.Y
  (a)Y
  (b)Y
    (1)Y
    (2)Y
  (c)N
  (d)N
  (e)Y
    (1)Y
    (2)Y
6.Y
  (a)N
    (1)N
    (2)N-UNK
  (b)Y
    (1)Y
    (2)N-UNK
    (3)N-UNK
      a.N-UNK
      b.N-UNK
      c.N-UNK
    (4)N-UNK
7.Y
  (a)Y
  (b)N-UNK
  (c)N-UNK
    (1)N-UNK
    (2)N-UNK
      a.N-UNK
      b.N-UNK

INERTIA

1.Y
2.Y
3.Y
  (a)Y
  (b)N
4.N-UNK
  (a)N-UNK
  (b)N-UNK
  (c)N-UNK
    (1)N-UNK
    (2)N-UNK
5.N-UNK
  (a)N-UNK
  (b)N-UNK
  (c)N-UNK
    (1)N-UNK
    (2)N-UNK
6.N-UNK
  (a)N-UNK
    (1)N-UNK
    (2)N-UNK
  (b)N-UNK
    (1)N-UNK
    (2)N-UNK
    (3)N-UNK
  (c)N-UNK
7.N-UNK
  (a)N-UNK
  (b)N-UNK
  (c)N-UNK
    (1)N-UNK
    (2)N-UNK
      a.N-UNK
      b.N-UNK

At T_2:

ACTION

1.Y
2.Y
3.Y
  (a)Y
  (b)N
4.Y
  (a)Y
  (b)Y
  (c)Y
  (d)Y
  (e)Y
  (f)N-UNK
    (1)N-UNK
    (2)N-UNK
*5.N (P=3)
  (a)Y
  *(b)N (P=3)
    (1)Y
    *(2)N (P=3)
  (c)N
  (d)N
  *(e)N (P=3)
    (1)Y
    *(2)N (P=3)
6.Y
  (a)N
    (1)N
    (2)N-UNK
  (b)Y
    (1)Y
    (2)N-UNK
    (3)N-UNK
      a.N-UNK
      b.N-UNK
      c.N-UNK
    (4)N-UNK
7.Y
  (a)Y
  (b)N-UNK
  (c)N-UNK
    (1)N-UNK
    (2)N-UNK
      a.N-UNK
      b.N-UNK

INERTIA

1.Y
2.Y
3.Y
  (a)Y
  (b)N
4.N-UNK
  (a)N-UNK
  (b)N-UNK
  (c)N-UNK
    (1)N-UNK
    (2)N-UNK
5.N-UNK
  (a)N-UNK
  (b)N-UNK
  (c)N-UNK
    (1)N-UNK
    (2)N-UNK
6.N-UNK
  (a)N-UNK
    (1)N-UNK
    (2)N-UNK
  (b)N-UNK
    (1)N-UNK
    (2)N-UNK
    (3)N-UNK
  (c)N-UNK
7.N-UNK
  (a)N-UNK
  (b)N-UNK
  (c)N-UNK
    (1)N-UNK
    (2)N-UNK
      a.N-UNK
      b.N-UNK

At T_3:

ACTION

1.Y
2.Y
3.Y
(a)Y
(b)N
4.Y
(a)Y
(b)Y
(c)Y
(d)Y
(e)Y
(f)N-UNK
(1)N-UNK
(2)N-UNK
*5.N (p=3)
(a)Y
*(b)N (P=3)
(1)Y
*(2)N (P=3)
(c)N
(d)N
*(e)N (P=3)
(1)Y
*(2)N (P=3)
6.Y
(a)N
(1)N
(2)N-UNK
(b)Y
(1)Y
(2)N-UNK
(3)N-UNK
a.N-UNK
b.N-UNK
c.N-UNK
(4)N-UNK
7.Y
(a)Y
(b)N-UNK
(c)N-UNK
(1)N-UNK
(2)N-UNK
a.N-UNK
b.N-UNK

INERTIA

1.Y
2.Y
3.Y
(a)Y
(b)N
4.N-UNK
(a)N-UNK
(b)N-UNK
(c)N-UNK
(1)N-UNK
(2)N-UNK
5.N-UNK
(a)N-UNK
(b)N-UNK
(c)N-UNK
(1)N-UNK
(2)N-UNK
*6.Y (P=1,3)
*(a)Y (P=3)
*(1)Y (P=3)
*(2)Y (P=3)
(b)N-UNK
(1)N-UNK
(2)N-UNK
(3)N-UNK
*(c)Y (P=1)
*7.Y (P=1)
(a)N-UNK
*(b)Y (P=1)
*(c)Y (P=1)
*(1)Y (P=1)
(2)N-UNK
a.N-UNK
b.N-UNK

(*) flags a change from T_0

(P=__) Priority level of condition

The priority of the condition becomes the priority of its associated concern.

A Discussion of Issues in Need of Resolution: Toward a Specification of the Decision Module

Paul A. Anderson
Department of Political Science
Ohio State University

June 1974
Project Research Paper No. 20

*The research described in this paper was supported by the Advanced Research Projects Agency Contract No. DAHC 15 73 C 0197.

Introduction

The goal of the project is the development of forecasting techniques to the point where alternative United States policies towards specific countries can be unambiguously ordered with respect to their utility in light of certain U.S. national objectives. As a means for attaining that goal, complex simulations of five Middle Eastern countries are being developed. The simulations consist of four modules. The oil, agriculture, and human resource modules are designed to reflect the environment that the decision makers in the various countries face. The modules describe the effects of a particular actions by the decision makers, as well as the actions that are available. In order to be in a position to evaluate the effectiveness of alternative U.S. policies toward these countries, we must know how the five Middle Eastern countries can be reasonably expected to behave. The purpose of the decision module is to give reasonable projections of the behavior of these countries (both foreign and domestic) in light of: 1) actions by the United States; 2) actions of other countries; and 3) changing "environmental" conditions, e.g., demand for oil, draught, etc. There are an infinite number of different behaviors (inputs to the three modules) that a country could exhibit (investment in agriculture, fertilizer usage level, oil production level, et cetera). The decision module must be able to determine which inputs each of the five countries can be expected to choose. The sector modules represent the choices--the decision module must make them. In addition to domestic sorts of behaviors, the decision modules must be able to reflect those foreign policy behaviors that the countries could be reasonably expected to exhibit.

Basic Properties of the Decision Module

There are three properties we believe characterize nations that have guided how we have approached the construction of the decision module: 1) Nations are goal seeking systems; 2) Nations hold a multiplicity of goals simultaneously; and 3) Nations are responsive to a perceived (rather than objective) environment.

At first glance the notion of a nation as a goal seeking system doesn't seem that unique. When we talk about the behavior of nations in ordinary (as opposed to theoretical) language terms we constantly make reference to teleological concepts, e.g., national interest or national goals. Consider a statement like the following: The Arabs cut-off our oil supply in order to influence our position on the resolution of the Middle East conflict. We are attributing to the oil producing Arab nations, goals (a preferred resolution of the Middle East conflict) and interpreting their behavior (the oil embargo) as an attempt to realize those goals. On the other hand, when we start to theorize about international relations in a scientific manner we do so in a language filled with notions of social forces (Rummel 1971) and correlates of war (Singer and Small 1972).

There are two points to be made in relation to nations as goal systems: 1) It is scientifically respectable to talk about purposive systems; and 2) Not only is it respectable, it is also fruitful to think theoretically about nations in terms of teleological systems. Social scientists still carry some of the scars that were left from the slaying of the structural -- functional dragon by the philosophers of science. Hemple (1959) and Merton's (1956) critiques of functionalism resulted in many scholars abandoning functional forms of explanation. General Systems Theory embraced the notion of telos, but the version of GST practiced in international relations strips away the heart of

the formulation, leaving only an empty input -- output shell with which to work. Many scholars in IR talk about adaptation, but one has the feeling that most of them really aren't quite sure about it, since once they leave the broad brush approach of verbal theorizing and start getting explicit, it's back to the old input -- output formulation of the nation. If one looks around at psychology, one finds a very different picture of the nature of the individual than was popular in the hey-days of behaviorism. Purposive system are respectable! As Miller, Galanter, and Pribram noted in 1960: "Once a teleological mechanism could be built out of metal and glass psychologists recognized that it was scientifically respectable to admit that they had known it all along." (Miller, et. al. 1960:43) The notion of goal seeking is central to Newell and Simon's work dealing with computer simulations of human problem solving (Newell and Simon 1972) Norbert Weiner (1961) has shown that one does not need to ascribe vital forces to an entity to call it purposive. The traditional mechanistic conceptions of behavior that we in international relations seem so comfortable with (in our theoretical work) is not incompatible with the notions of goal seeking.

A second characteristic that we believe is descriptive of nations is that they hold several goals simultaneously. As will be discussed more fully below, it is this property that differentiates efforts by economists at the specification of a firm or individual as a goal seeking system from the efforts of political scientists and psychologists to treat behavior as a product of a goal directed system. Economists can treat the firm as if it had only one goal, the maximization of profit, subject to certain constraints. On the other hand, when dealing with nations or individuals political scientists and psychologists must deal with the fact that there is no single goal which can adequately describe the operation of the system. If the goals of the system are inconsistent (as is often the case) one goal be achieved only at the expense of another. In

that case, the system (nation, organization, or individual) must determine what sorts of trade-offs are acceptable. Even if the goals are consistent, because the systems have only a finite amount of resources, all goals may not be achieved at the same time. Again the system must decide what allocation of resources is in some sense optimal.

The third characteristic that we posit of nations is probably the most well accepted in the field today. Ever since the efforts of Snyder, Bruck, and Sapin's Foreign Policy Decision Making (1962), the "man -- milieu hypothesis" of the Sprouts (Sprout and Sprout, 1956; 1965), and the investigation of crisis decision making by the Stanford group (Holsti, 1965; Holsti et. al. 1965, 1968; North et. al. 1963) scholars in international relations have realized that what counts as far as the decision maker is concerned is what the decision maker(s) perceives to be real, rather than some 'objective reality" gleamed on the part of some analyst. While it is recognized that objective reality is an illusion, the efforts that have taken perceptions seriously have primarily been concerned with demonstrating the effects of perceptions of the situation. Very little has been invested in the investigation of the process of perception per se. If we are to be in a position where we can give reasonable projections of the behavior of the five Middle Eastern countries, we must determine how they process inputs from the environment. What aspects of the environment are the decision makers most sensitive to; how do they interpret those aspects; how do they react to changes in those aspects; what elements of the environment are they likely to miss because of the method by which they encode the myriad of incoming stimuli?

Prelude

These three characteristics that we posit of nations have guided the manner in which we have attempted to specify the properties that the decision module must have, and they have led to a fairly clear specification of the issues that are in need of resolution if a working decision module is to be built. The remainder of the report will consist of 1) a specification of the issues that must be resolved; and 2) a discussion of the framework with which we propose to resolve the issues.

The issues that are in need of resolution can be grouped into two classes. The first are those that are derivative from the specification of the nation as a goal seeking system. The second follow from the fact that nations cannot be adequately conceptualized as having only one goal.

The structure in which we are attempting to resolve these issues is composed of two interrelated concepts: 1) the notion of production systems as a means for expressing the operation of the decision processes within each of the five countries; and 2) the notion of a grammar which specifies the language with which the nations communicate with the domestic sector modules, channel internal bureaucratic flows, and communicate with other international actors.

Elements of Goal Seeking Systems

There are three basic elements of any goal seeking system -- receptors, effectors, and a decision mechanism. Receptors scan the environment. The decision mechanism compares the picture of the environment that the receptors send with the system's preferred environment. The decision mechanism then decides on appropriate actions to bring the environment closer to the goal and sends instructions to the effectors to take those actions. At that point the process starts again --- perceive, compare, decide, react . . . and so on. Using this notion of the nation as a goal seeking system, behavior simply becomes the system's attempt to steer or control the environment closer to some desired goal state (Cf. Simon 1969). While the notion of steering is central to the argument that Deutsch (1966) makes in his Nerves of Government, the conceptual model that he presents is very heavily influenced by the concepts of information flow and communication. Less central in his analysis is the notion of the decision mechanism and how it works.

The receptors play a very crucial role in the determination of the behavior of the system. A nation, or any other goal seeking system, cannot respond to features of the environment that it doesn't think is there. Because of the complexity of the environment that the system is surrounded by, the system cannot observe all features of the environment. The system selects some features of the environment as important and the receptors are only sensitive to changes in those features. While the problem of measurement taken on the "real" environment will always be problematical, as will be the process by which the information about the environment is transmitted to the decision mechanism, for the time being it will be assumed to be perfect. The problem now becomes

one of what sort of features of the environment are important. Since the totality of the environment cannot be scanned, some elements of that environment must be selected as important. When dealing with human systems, it is helpful to use the notion that the system has some model of how the environment works. Included within this model are the set of important variables which may impact on the ability of the nation to meet its goals. The decision maker's (or mechanism's) model of how the environment works "tells" him which feature of the environment are important and should be attended to. Thus the receptors are only sensitive to those variables that the decision maker's model says are important. It also follows from this that the environment that the decision mechanism is "really" responding to is not the environment itself but some image of the environment.

The images that the decision mechanism has of the environment it is responding to also plays a crucial role in the operation of the decision mechanism itself. The decision mechanism takes the inputs from the environment it has instructed the receptors to measure and compares that information with the stated goals of the decision system. The decision mechanism then evaluates the degree of correspondence between the goal state and the perceived state of the environment. Thus the image of the environment the decision mechanism has, specifies not only the important variables but also the relationships between them. Based upon the perceived way the world works and its perception of the degree of goal achievement, the decision mechanism determines changes in its outputs it expects will in some manner "maximize" its goal achievement. (While more will be said on the manner in which the decision mechanism makes changes in its output

variables, this basic notion will be sufficient for now.)

The only other step remaining in the functioning of the system is the communication of instructions for changes from the decision mechanism to the effectors, or the access interface with the environment (Cf. Thorson 1972). As was the case of the receptors, we shall assume the communication channel between the decision mechanism and the effectors is perfect. We will also assume the receptors are capable of carrying out the instructions of the decision mechanism.

Conceptually at least, this completes the specification of a goal seeking system. While it is known that the operation of the effectors and the receptors is by no means unproblematical -- the bureaucratic politics "paradigm" (Allison 1971, Allison and Halperin 1972) is centrally concerned with the contingent character of these processes -- it simplifies our conceptual model greatly to make this assumption. Since we have made these simplifying assumptions about the nature of the receptors and the effectors, we are now in a position to begin talking about the decision process and the role of environmental images or models in the operation of the decision mechanism. It will be recalled that there were three steps specified in the operation of the decision process: 1) A comparison of the degree of difference between the observed and goal environments; 2) The use of the decision mechanism's image of the environment to "predict" changes in the environmental state as a function of the behavior of the effectors; and 3) A choice of effector actions based upon some sort of "maximization" criteria applied to goal achievement. They will be dealt with below in the order presented above.

We really aren't sure what calculus decision makers use in determinating goal achievement. Common sense would indicate that the decision

mechanism is not physically capable of considering all goals at the same time. In fact it could be argued that the receptors are only capable of scanning a proper subset of the variables the decision mechanism would like to scan. One factor that must be dealt with is since the system cannot be equally cognizant of all goals and their associated environmental indicators, at any given point in time the decision mechanism must in some manner select those goals to which it will be attentive. The question becomes: By what process are certain goals selected for more attention than others? Another issue that becomes important in this context is, once the environment has been scanned with receptors sensitive to only a subset of the "important" variables, how does the decision mechanism rank order all possible environmental states with respect to goal achievement? Notice that for a simple decision mechanism, a servo mechanism for example, there is only one goal. In this case the process of goal attentiveness or the definition of a preference ordering of all environmental states is straight forward. Consider a servo mechanism attached to the motor of a phonograph turntable. The goal is a rotation speed of 33 1/3 revolutions per minute. The environmental state is the actual speed of the rotation. The servo mechanism can easily define a preference ordering over all environmental states. To further simplify the example let us suppose that the mechanism finds any speed other than 33 1/3 revolutions per minute equally undesirable. The system finds the decision as to which environmental variables to monitor and which goal to be attentive to unproblematical. Thus the servo mechanism has the task of monitoring the speed of the rotation of the turntable (or some analog for it) and adjusting the speed accordingly. But it is not unproblematical how often the receptors scan the environment. This point will be discussed in more detail below. In a situation

where the system is faced with two or more goals, it must somehow determine a preference ordering over all of the possible environmental states. In the case of the servo mechanism there was only one goal; instead consider the case of a person in the midst of an energy shortage. The individual has two goals -- save energy and maintain a certain level of comfort. (The fact that these goals can be considered mutually exclusive makes the point clearer, but does not imply that this relationship holds only in the case of mutually exclusive goals.) The issue the individual must face is whether saving energy or staying warm is more important. Is the dissatisfaction greater when the room is cooler than desired, but more energy is being saved -- or the situation when the room is comfortable, but energy is not being conserved? The question is not merely so simply as it was when there was only one goal. One solution that is often posed for this type of problem is the introduction of something called utility. All one needs to rank order the possible environmental states is a utility function over them. Unfortunately utility is easier posited than measured. Using the notion of utility in the above example, the vector of goal differences would be computed by subtracting the goal room temperature and the preferred energy usage rate from the actual temperature and the actual energy rate. The elements in this goal difference vector would be multiplied by a vector of utility/dimensionality constants, and the resulting scalar would be the amount of total goal dissatisfaction. Unfortunately that process carrys with it many assumptions that seem to evade empirical test. Until the problem of vector maximization has been worked out, we will have to be satified with utility -- its all we have got. As will be indicated below, this problem of preference over environmental states

crops up again when the decision mechanism is faced with determining what set of output (inputs to the environment) will maximize goal satisfaction. The resolution to this problem becomes crucial when the decision mechanism does not have the resources or the capability to achieve all of its goals at the same time.

Even though the problems outlined above have not been solved, let us assume that some suitable preference ordering over all environmental states has been achieved, and that we know how the decision mechanism evaluates the various possible mixes of environmental states. (which defines the preference ordering). The next topic that will be considered will be how the decision mechanism "decides" what is the "best" way to decrease goal dissatisfaction. The major assumption or observation about the ability of humans to make decisions that is crucial to this element of the process, is that humans do not have the capacity to consider all of the possible variables they could manipulates; they do not have sufficient information at their disposal to accomplish that task, even if they had the power to do so; and finally since the decision mechanism must depend upon its fallable mental model of how the system works, even if they had all of the information and the ability to process it, they are not sure enough how the world works to make a "best" choice. One of the first to recognize that humans were not the "all powerful and rational beings" that much of decision theory held them to be was Herbert Simon. Simon (1955) introduced the notions of satisficing and bounded rationality as descriptions of how men really behaved. Under Simon's conception of the decision process, decision makers did not search until they found the "ideal" best solution, but rather they looked until they found one that they thought was good enough. Once they found

a solution that satisfied their minimum criteria of acceptance they stopped looking. This notion of the decision process seems very close to the manner in which decision makers seem to behave. Using this conception of the decision process, the decision mechanism takes the amount of goal satisfaction and compares it with its satisficing limit. If the amount of the dissatisfaction is less than the minimum amount of dissatisfaction, the decision mechanisms declares that all is right with the world and goes back to sleep until the next measurement comes in from the receptors. An alternative conception of the decision process would posit that the decision mechanism, if it perceives any goal dissatisfaction will search for an alternative solution. But, if the initial amount of goal dissatisfaction is less than the minimum level, the decision mechanism will simply try to better the current situation -- and not search until it finds a set of inputs that it thinks will lead to complete goal attainment. Using this alternative representation of the satisficing notion, the decision mechanism always searches, but depending upon the level of the current dissatisfaction its search for alternatives will be more encompassing and further reaching if the goal achievement is below the satisficing limit. The choice between these two competing interpretations of the behavior of the decision mechanism under a satisficing sort of procedure is not really decidable on an a priori basis. It could be either way. The only way that a determination can be made is by the actual observation of decision behavior.

Once the decision mechanism has decided whether or not it is going to search, and how broadly it is going to search, the decision mechanism is faced with finding a set of outputs that will increase the current level of goal achievement. The decision mechanism uses its mental model to project the state

of the environment based upon its behavior. The mental model, as was mentioned above, is not a perfect one. One would expect that the relationship specified in the model would be fairly close to the manner in which the world really worked, (otherwise the decision mechanism would have been replaced either by some orderly means, or it might have destroyed itself). The decision mechanism searches for sets of output values for the variables that it thinks are important and checks, by means of its model, whether or not it can be reasonably expected the outputs will achieve their intended consequences. Since the model is not perfect they will make mistakes. Since the decision mechanism has some idea of how the world works, one would expect that its search for variable values would not proceed in an entirely random basis. Derived from the model and experience would be some expectations as to the effects of various outputs on the behavior of the environment. It would be expected that the decision makers would use these expectations as a guide in their search. How it will not always be the case that the decision mechanism proceeds in a totally "rational" fashion. If the basic model that the mechanism uses to think about the environment is bad, inconsistent, or largely unspecified, the search behavior would be expected to be influenced accordingly. Another factor that would influence the pattern of search behavior would be the complexity of the conceptual model. A model, fairly complex and sensitive to the various inputs the decision maker can feed it, would be expected to result in a very different pattern of search behavior than would a model based upon some very gross and crude notions about how the world works. The search behavior could also be greatly influenced by the manner in which the decision mechanism defined its preference ordering over the environment. If it thought that one variable in particular was useful in decreasing the dissatisfaction of one of the major goals was the major goal that largely was responsible for

the under achievement it could be expected the decision mechanism would spend more time searching along that one variable for possible candidates than it would on another variable considered less central. Needless to say, the interaction between goal achievement and alternative search is strong.

While it has not been mentioned specifically, when the decision mechanism thinks that it has a possible candidate for decreasing the dissatisfaction, it uses its model to determine the expected performance of the system given those inputs. If effect the system generates the expectations of what the receptors will be sending it on the next decision cycle, contingent upon that particular set of inputs being applied to the environment. If the proposed solution takes the (or at any rate the decision mechanism thinks it takes) it further away from its goal, the decision mechanism will try a different route. On the other hand, if the mechanism perceives that a particular class of the manipulable variables is taking it closer to its goal, it will continue search in that same direction. The decision maker will continue searching until either one of two things happen: 1) A proposed input mixture brings the goal satisfaction below some level; or 2) Some sort of time or length of search limit has been reached. In the first case there are two possible interpretations for the behavior of the decision mechanism. One case, already mentioned above, is when the minimum acceptable absolute level of dissatisfaction has been reached. Another possible interpretation is that the decision mechanism does not search for some absolute level, but rather for a relative increase in goal achievement. Using this second notion, the satisficing criteria might be something like: Decrease the current dissatisfaction by 30%. The time limit criteria is needed for those cases when the decision mechanism is not able to locate a set of inputs that would bring the goal achievement up to some minimally acceptable level. Since it is assumed that there is some urgency associ-

ated with the decision process, when the time or length of search limit has been reached, the decision mechanism will take the best alternative that it has uncovered so far and use it, hoping that it can find something better next time.

There is one other point that should be made in relation to this act -- observe -- decide -- act cycle. The length of time between act and observe, i.e., how often observations are taken on the environment, has implications for the behavior of the decision mechanism. If the time period is too long, the system may experience such a deviation from the goal state that it collapses. On the other hand if the observations are taken too often, the actions of the decision mechanism may not have had time to achieve their intended consequences. If it is the case that the receptors are instructed to take observations at a rate faster than the environment is capable of responding to the decision outputs, one could expect the net effect would be the decision mechanism would over-compensate in its levels of the output variables, causing the behavior of the system to widely oscillate around the goals. Thus in the ideal case, one would want the receptors to take observations on the environment at a rate such that the environment had time to "respond" to the decision mechanism's outputs. (For some systems an appropriate rate would be somewhat slower than the environment, if it were the case that it took several environmental "cycles" for the full impact of the effector's outputs to become known.) But as was noted above, the conception that the decision mechanism can know the environment in totality is a false one. It therefore follows that if the model is to be of use the system must have some learning capabilities. The mechanism must be capable of fine tuning its model to more accurately reflect the dynamics of the environment that it is facing. What this learning process would look like is an open question, but one would expect that it would essentially involve the

comparison of the behavior of the environment with the behavior predicted by the decision mechanism's model. Based upon that comparison, one would expect there would be some sort of iterative process where changes in the mode's structure would be compared with the change in the accuracy of its predictions.

This completes the discussion of the decision process element of purposive systems. To recapitulate, the system is composed of receptors that scan the environment on certain key variables, a decision mechanism which determines the level of goal achievement and chooses an appropriate strategy determined by the decision mechanism. The next part of this paper will be a consideration of the applicability of some goal seeking systems approaches that have been used in economics to ascess their applicability to the field of international relations.

Single versus Multiple Goal Seeking Systems

While both psychology and economics have used the concept of goal seeking as the basis for the analysis of human behavior, economics with its "rational man" model has probably invested more time and resources into questions of goal seeking behavior than any of the other social sciences. Of particular interest to political scientists has been the work dealing with theories of the firm. In the theories of the firm, economics has been centrally concerned with Simon's concepts of satisficing and bounded rationality (in fact, Simon introduced those concepts in order to deal with the behavior of the firm). One recent attempt to deal with this problem has been the work of Nelson, Winter, and Schuette on technological growth and evolutionary change (Nelson and Winter 1972, 1973; and Nelson, Winter, and Schuette 1973). While this is not the place to go into a detailed discussion of what their theory of growth looks like, the following observations can be made about it.

Nelson et. al. have modeled their firms (or goal seeking systems) as facing an environment of prices, labor, and capital. The goal of the system is to maximize profits. The amount of the good the firms produce is determined by the investment of capital and labor. The constraints the firms face deal with the wage rate and the price that they can get for their product. The question that Nelson et. al. are attempting to deal with is what are the dynamics that will lead a firm to use different scales of production, i.e., the amount of labor and capital, in attempting to maximize their profit.

As was discussed earlier, a goal seeking system must have three elements -- effectors, a decision mechanism, and receptors. In order to evaluate the Nelson et. al. formulation, these three structures in their theory will be analyzed. As is often the case with social theorizing, Nelson et. al. have assumed away receptors and effectors by allowing their firms to have perfect perception and control. In other words the effectors carry out exactly the directions of the decision mechanism, and the receptors perfectly measure the profit for the current input coefficients (labor and capital). The element of the system that Nelson et. al. pay most attention to is the operation of the decision mechanism. As will be recalled from the above discussion, some properties of the decision mechanism are the inability to be "globally rational", and the use of models of the environment to predict or forecast the behavior of the environment contingent upon certain outputs from the system. Nelson et. al. deal with the satisficing notions of Simon by setting a minimum level of return on investment that the firms will be satisfied with. This minimum level of profit is the satisficing limit discussed above. They further incorporate the notions of search for alternatives by positing that their firms, when faced with a profit level below their satisficing limit, will search for alternative input coefficients to increase their profit above

the minimum level. In their specification of the search algorithm for their firms, Nelson et. al. posit the firm will search for and consider a larger range of alternatives the greater their dissatisfaction. This is not saying that a larger number of alternatives will be considered, but rather the probability an alternative very "far" from the current set of input coefficients will be considered is greater, the greater is the dissatisfaction with the current set of input coefficients. Nelson and Winter also give their decision mechanism a model of the environment with which to test the profitability of a given alternative. The model the firms employ to forecast the effects of a given level of labor and capital does not perfectly reflect the actual behavior of the environment. The model distorts the proposed input coefficients according to a probabilistic sort of procedure so that the decision mechanism has an equal chance of under or over estimating the profitability of a given set of input coefficients.

It seems that Nelson et. al. have included most of those elements of goal seeking systems that were mentioned. Unfortunately the one that they don't deal with, while not crucial to their work in economics, seriously detracts from the applicability of their work in international relations. It will be recalled that one of the problems that the decision mechanism must face is the definition of a preference ordering over all environmental states. As was pointed out, this problem is not too difficult when only one goal is being held by the decision mechanism, but it reaches very great and problematical proportions when the single goal restriction is lifted. While the assumption of a single goaled system is central to economic theory, when we think about international relations, we see that the nations hold more than one goal at the same time. It is not that the problem of multi-goaled systems cannot be handled, but just that the conceptualization necessary

becomes a conceptualization of a different kind. Somehow the notions of multiple goals, how they are weighted, the factors influencing their weight, and how they change over time must be dealt with. Before we can start to talk about the behavior of a nation under some form of the satisficing criteria, we must have a very definite notion of what the decision mechanism is attempting to maximize. Thus the crucial difference between goal seeking systems economists have developed and the goal seeking systems international relations scholars would like to develop, while being of the same class, are of very different types. Where economics can make the assumption that the sole goal of the firm is to maximize profits, international relations is not in a position to posit some single thing that nations maximize (other than utility). Thus in order for international relations to make use of the goal seeking systems approaches that have benefitted economics, additional conceptualization will be required.

Multi-Goal Seeking Systems

When one leaves the realm of single goal seeking systems two problems immediately arise: 1) How does the decision system rank order the goals in terms of importance; and 2) How do the goals of the decision system change as a function of time, the environment, and experience? The question of ranking becomes crucial since it will be the case that either the goals are inconsistent, i.e., one goal can be achieved only at the expense of another, or because of finite resources not all goals can be achieved at the same time. In order for a decision system to operate in such an environment, it is necessary that the decision system somehow rank the goals in terms of importance. This ranking or ordering of goals has several implications for the operation of the decision mechanism. As will be recalled from the above discussion on goal seeking systems, the system cannot be attentive

to all aspects of the environment at the same time. It must choose those aspects of the environment that it is trying to control will be paid attention to. These facets of the environment that the system will monitor will be influenced by the goals that the system is attempting to achieve (it will monitor the performance of variables that reflect the amount of goal attainment). The causal image the system has of the environment will also influence those aspects of the environment to which it will be attentive. Given the same goal (reduce inflation), depending upon the causal image that the decision system has of the environment (Friedman or Samuelson) the system will pay more attention to a particular economic indicator than the other. It will also apply different controls depending upon the causal theory. Thus the behavior of the system is a function of 1) the goals that it has; and 2) the causal theory or image the system has of the environment. Since both the causal theory and the goal structure is open to change, knowledge of only one of them is insufficient for the determination of the behavior of the system. This brings out the importance of goal change. In order to give reasonable sorts of forecasts of the behavior of the system we must know how the goals of the decision system change. The goals of a system can change in two sorts of ways. Either the ordering of the goal structure may change, or the content of the goal structure may shift. This second sort of change can either be a result of old goals being deleted, new goals being introduced, or both. It therefore becomes important to know by what process and under what influences the goals are ordered, and the nature of goal change.

Just about the only effort to date that has seriously considered the nature of goal rankings and change has been the work of Bossel and Hughes (1973) in the context of the Mesarovic-Pestel World Model Project. As an aid to the identification of the issues involved when dealing with multi-goaled

decision systems, their work will be discussed from the perspective of the issues that they see as important and their attempt at their resolution.

Bossel and Hughes make the argument that the normative components of a decision system are hierarchically ordered sets of three types: values, general goals, and operational goals or norms. For Bossel and Hughes, there is no clear distinction between these three types of normative elements. The only thing that distinguishes a value from a general goal is the level in the hierarchy (or abstractness) of the component. Values, or superior norms, give an overall direction to the decision making effort; general goals are determined from the values and control the policy choice; operational goals or norms derive from the general goals and control the individual decisions. As an example consider the value of the system to be survival. From this value there might be the general goals of preservation of vital resources and the maintenance of health. Flowing down from these two goals might be the operational goals or norms of saving energy, saving water, save materials (from resource preservation), and moderation in eating, drinking, and work (from the preservation of health). Bossel and Hughes have conceptualized this collection of norm elements as being the nodes of a tree graph. See Figure I for an illustration of this norm structure taken from Bossel and Hughes. Bossel and Hughes characterize the norms structure as follows:

- Norms are characterized by location in the normative structure.
- The quantities characterizing norms (location, content, weight) and the dynamics of norms change are fuzzy concepts.
- Inconsistencies with the norms stratum (with respect to structure, content, and weight) will tend to be minimized.
- Norms contents are generally expressed as verbal statements.
- Norms contents and structures generally change by discrete amounts.
- As relative norms weight decreases, the relative uncertainties associated with norms location, content, and weight increase.

(Bossel and Hughes 1973: Sec. 3.2)

The notion of location has already been discussed; it refers to the position of the node in the graph. The content or state of a norm (node) is the statement associated with it, e.g., preserve vital resources. The weight associated with a norm rank orders the norm with respect to the needs (or desires) of the system. Under Bossel and Hughes' conceptualization of the norm or value structure, the weights are subject to dynamic change as a result of changes in superior norms and of real or imagined consts and benefits derived from holding and applying a certain norm. Bossel and Hughes point out that different weights to the norms at different times will give rise to quite different decisions about comparable issues. This falls in line with the above discussion about the importance of goal orderings for the behavior of the decision system. Bossel and Hughes have conceptualized the manner in which weights influence the decision process by stating that the content and weight of the values (abstract goals) will determine the content of the operational goals (the specific things the decision system wants to achieve) and the manner in which the system will order the goals, the weights.

The way Bossel and Hughes have conceptualized the norms structure, there are three modes of change of the norms structure: 1) there may be a change of the norms content; 2) there may be a change in the structure; and 3) there may be a change of the norm weights. A change in the norms content means that while the linkages between the various norms in the structure remains unchanged, but the meaning of a particular node in the structure is altered. A change in the structure means that either new linkages are formed between existing norms, or that an additional norm or value is introduced into the existing structure. A change in the weight means that the importance of a particular norm to the system changes. It is important to note that weight implies importance to the system irrespective of the state

of the environment. For example if the maintainence of an adequate supply of water is a goal of the system, no matter how much water there is in the environment, the weight of the particular norm concerned with the necessity of water will remain unchanged. Now it will be the case that the operational goal of the system pertaining to water conservation will be relaxed, i.e., the system will not have as one of its primary goals the conservation of water.

Bossel and Hughes have posited four basic mechanisms that are responsible for changes in the norms structure: 1) adoption; 2) adaption; 3) imposition; and 4) diffusion. The first two types of mechanisms are what could be considered conscious. The structure is changed by the process of adoption by the conscious change of an old norm of the planned introduction of a new one, or the willful change of norm weights. Bossel and Hughes state that this process is undertaken as the result of observation of the environment, and that usually it will take the form of adoption of a norm from a list of ranked priorities which the system keeps and modifies according to the circumstances it finds itself in with respect to the environment. The norm will be adopted if the system "thinks" it will be able to handle the consequences. Imposition is a change dictated by an outside force. An example are the norms and values imposed by occupational forces. The norms structure is changed through the process of adaption in response to either changes in the environment or within the system itself. Adaption is much like adoption except that it is not a conscious change and generally takes place at a rate much slower than imposition (which is the fastest) or adoption. The process of diffusion is a means toward consistency within the norms structure itself and is not an autonomous source of change. The processes of adaption, imposition, and adoption will generally affect only portions of the structure.

The process of diffusion attempts to reconcile these changes with the rest of the value structure. The diffusion process can take place either from the top down (what Bossel and Hughes call downward diffusion) or from the bottom up (upward diffusion). In the case of bottom up diffusion, superior norms are changed in response to changes in lower or inferior norms. Top down diffusion is just the reverse -- lower norms are changed in response to an initial change in the upper portion of the norms structure.

In order to link the norms structure to the decision process and the environment, Bossel and Hughes introduce the concept of monitor variables. As can be seen in Figure 1, assigned to each operational norm or goal is a monitor variable. Paired with the operational goal of save energy is the monitor variable measuring the current energy supply. Now it will not generally be the case that there will be a one to one pairing of monitor variables and goals. The system determines the monitor variables as a function of the specific goals in addition to the causal image the system has of the environment it faces. The manner in which Bossel and Hughes have conceptualized the linkage between monitor variables and the system's goals is at the top of the hierarchy and not at the specific operational goals. For illustrative purposes consider the example that Bossel and Hughes use in their simulation of a valued controlled decision system. The simulation is concerned with the energy sector. Sample nodes from the value structure are concern about the future, concern about dependence on imports, concern about the harmful effects of pollution. A few of the goals are level of energy imports, goal for industrial output per capita, and the energy consumption per capita. Examples of the monitor variables that they use are level of industrial development, perceived level of pollution, negative balance of payments, and uncertainty about technological progress with respect to energy supply. As they have conceptualized it, changes in monitor variables

will cause changes in the values. These changes in the value structure will cause additional changes in the values because of their interrelated nature. The combined effects of changes in the values caused by the monitor variables and internal value changes will result in the change of specific goals of the system. If it were the case that the monitor variable, perceived level of pollution increased, one would expect changes in the values of expectations about the standard of living, harmful effects of pollution, and concern about the efficiency of energy usage. These changes could be expected to decrease the specific goal of energy consumption per capita.

While Bossel and Hughes talk about changes in the content, weight, and location of values through the processes of adoption, adaption, imposition, and diffusion they only simulate and get explicit about changes in the weights of the various norms through the processes of adoption (the effects of monitor variables on values) and diffusion (the effects of changes in values on the value structure itself). They do not explicitly state exactly how the processes of adaption and imposition work. Nor do they begin to deal with changes in the content and location of the value nodes. While this is not meant to degrade their efforts, it does point out how far we have to go in order to begin to talk about the process of change in the value or norms structure. They are one of the few to have recognized that the problem even exists.

Currently our efforts in regard to the goal structure of the five Middle Eastern nations is primarily directed toward the identification of the goals (at all levels of abstraction). Exactly how we propose to incorporate the elements of value controlled decision making in our simulations will be discussed more fully below. It is our predeliction to embed the normative components of the decision process directly into the simulation structure, rather than have it as a separate structure as Bossel and Hughes have done.

Production Systems: A Theory and Language for Process Models

Allen Newell has stated that with regards to cognitive psychology in order to "predict (the behavior of) a subject you must know: (1) his goals; (2) the structure of the task environment; and (3) the invariant structure of his processing mechanisms. (Newell 1973a:293) Since Newell et. al. have approached the simulation of cognitive psychology from an information processing standpoint, in the same manner as we view the nation, we feel that there is much to be gained from the cognitive psychology literature. The notion of goals has been discussed previously. The structure of the task environment is identical to the manner in which the system perceives the environment it is attempting to control. Production systems represent a means for expressing the third element in Newell's list -- the structure of the processing mechanism.

When one sets out to build a process theory or model of some phenomenon, one of the first steps is the identification and exposition of the constituent parts of the system. In the case of Bossel and Hughes, they developed the notions of value, diffusion, weight, et cetera. Once the parts and sub-processes of the system have been identified, they must be put together to form a process model. As Newell (1973a) has pointed out, this putting together of the parts of the model is generally an informal affair, very poorly specified. What Newell has called the control structure is rarely specified. The control structure specifies how the system is to be coordinated, the timing of the various events, what order certain operations, tests, and processes are to be performed, and the step by step operation of the various processes. It generally seems to be the case that the control structure is ignored by the theoreticians and specified by the computer programmers (and even the programming language writers). The theoriticians may be able to give some theoretical basis for a general flowchart of the operations of

the system, but a flow diagram is much too informal a method for the specification of theory. Very often the choice of a programming language will go a long way toward the specification of the control structure. The sequencing of the computations in a program, even large blocs of code may be determined by the pecularities of the programming language. The programming language will actually control the way in which the theory can be expressed. What passes notice in many efforts is that the "architecture of the system" has very real implications for the operation of the system and the predictions that it makes. Common programming languages are not neutral affairs. The common problem orientated programming languages (FORTRAN, COBOL, PL/1) were designed to be neutral only for a very specific class of problems. FORTRAN (FORmula TRANslator) was designed to handle algebraic sorts of manipulations. As long as the problem involves simple computing of numbers FORTRAN is neutral. But if the problem contains more than just a system of algebraic equations, FORTRAN is a very biased language. Some operations are simply impossible to execute in FORTRAN. Unfortunately theories are not always simply strings of addition and subtraction. If an inappropriate language is used, the theory must often be compromised because of restrictions and pecularities of the programming language. At the same time, there is too much freedom, since the general purpose language will "allow" choices to be made about the architecture of the system that have serious implications for the way the theory works. Very often it is not realized that the choice has even been made.

Production systems represent a different form for describing processing models - a theory laden programming structure. Production systems explicitly incorporate theoretical assumptions. They restrict the types of expressions allowable in the language , and provide a means of expressing the control structure explicitly. In fact they force one to be explicit about the control structure by making it an integral part of the specification of the process. Production

systems have been used in psychology (Newell, 1973b,1966; Newell and Simon, 1972) for the expression of theories of human problem solving. As will be discussed in the section on grammar, production systems also have another use -- the specification of a language along with grammatical sentences in that language. Thus we will be using production systems in two senses. One for the specification of the processes, and secondly for the way in which the nations communicate with the environment.

Processing models written as production systems are formed by a collection of independent rules, called productions.* The rules (or productions) are stated in the form of a condition and an action: <u>C→A</u>. The condition refers to the symbols in the short-term memory (STM) of the system. (The role of STM in national decision systems will be discussed more fully below. For the time being it will be sufficient to note that the STM is in effect a stack of symbols.) The contents of STM represents the goals and knowledge elements existing in the system's knowledge state. As Klahr (1973:528) has put it, the actions of the productions "consists of transformations on STM including the generation, interpretation, and satisfaction of goals, modification of existing elements, and addition of new ones." A production system obeys simple operating rules:

i. The productions are considered in sequence, starting with the first.
ii. Each condition is compared with the current state of knowledge in the system, as represented by the symbols in STM. If all of the elements in a condition can be matched with elements (in any order) in STM, then the condition is satisfied.
iii. If a condition is not satisfied, the next production rule in the ordered list of production rules is considered.
iv. If a condition is satisfied, the actions to the right of the arrow are taken. Then the production system is reentered from the top (Step i).
v. When a condition is satisfied, all those STM elements that were matched are moved to the front of STM.
vi. Actions can change the state of goals, replace elements, apply operators, or add elements to STM.
vii. The STM is a stack in which a new element appears at the top pushing all else in the stack down one position. Since STM is limited in size, elements may be lost. (Klahr 1973: 528-529)

---

* This discussion of production systems relies heavily on Klahr (1973)

As a simple example of a production system consider the illustration in Figure II. The first four lines are the individual productions. The fifth is the short term memory (STM). The operation of the production system starts at the top. The condition for the first production is AA and BB. Since these two elements are not in STM, the next production is checked. It is not satisfied. This process continues until production 4 is checked. The symbol AA is in STM. This production is then executed, and the symbols CC and DD are placed in the STM. This causes the last two symbols in STM, RR and SS, to be lost, since the maximum number of symbols in the STM is five. Control is then passed to the top of the production system and the first production is checked. The first production that is satisfied is production 3. As is explained in the above list of rules, those symbols that satisfy the production are moved to the top of the STM. Thus the STM before the action portion of the production is executed is: (DD (EE FF) CC AA QQ). Production 3 results in the symbol BB being placed in the STM and QQ is lost. Notice that even though production 4 is also satisfied, it is not executed. Only the first production in the list that is satisfied is executed. (If it happened that no production were satisfied, the program would form an infinite loop.) Control is then passed to the first production. The condition portion of the production is specified and the action taken. The OLD ** operator is a replacement operation that modifies the contents of STM. After the matched symbols have been moved to the top of STM the first symbol in STM is replaced by (OLD **), where ** is replaced by the first symbol. Thus after the action is taken, the contents of STM is: ((OLD AA) BB DD (EE FF) CC). The system then loops back to the top and production 2 is evoked. The effect is to move the test symbols CC and BB to the top of the STM and to emitt the statement III. On the next

cycle, production 2 is again satisfied and the system says HI. The system as written will continue to cycle through saying HI until someone pulls the computer's plug. If the second production had been written as: (CC and BB → (SAY HI) (OLD**)), and the following production inserted immediately before production 2: ((OLD CC) → (STOP)), the system would have shut itself off after saying HI once.

One of the striking things about production systems is that the control structure is exposed. The order in which the productions are ordered has very real consequences for the operation of the system. If production 4 were moved to the top, the system would have continuously cycled through executing that production forever. While this system may not be the best example, the behavior of the production system is very much influenced by the order in which they are executed. The next production system is an instance where the order of the productions will make a great difference in the behavior of the system.

The production system in Figure III is an example with more theoretical interest than the preceeding one. (Although it should be noted that in terms of complexity and the resolution of the issues raised in this report, the system in Figure III bears about as much resemblance to our goal as does the flowchart for making fudge that is used as an illustration of a program in introductory programming texts.) The production system in Figure III is a system that attempts to describe the behavior of the Libyan Revolutionary Command Council. Recently Kaddafi was asked to step down from his political-diplomatic position but retain his position as Commander-in-Chief of the Libyan armed forces. The example production system is an attempt to specify those conditions under which the Council will request that Kadaffi step down (or go to the desert for meditation). This production system was built upon the assumption that the reasons that Kaddafi was asked to step down amount to the perception on the part

of the members of the Council that things are not going well for Libya. Some of the indicators or monitor variables that the Council might consider are: fiscal irresponsibility, food shortages, excessive religious orthodoxy. It was also assumed that the Council was more willing to ignore some of the bad points if there were favorable aspects of the situation to off-set the bad points (or as they are expressed in the production system, marks). Thus if Sadat looses face, there is an increase in skilled labor, or if there is a food surplus (relatively), the council will overlook some of the bad points about Kaddafi's management. If it is the case that even with the good points, Kaddafi has managed to accumulate four marks, the Council will request his resignation. The actual operation of the production system is very much like the preceeding example. Initially the STM of the Council is filled with NIL or blank symbols. Since none of the first 15 productions will be satisfied, the sixteenth production, which contains no condition and will always be executed if none of the other productions are satisfied. The action READ means that the Council looks at the environment and takes a reading of the current state. As long as the symbol read from the environment does not invoke a production, the system will continue reading until one is found. Let us say that the first "recognizable" symbol is a food shortage. After it is placed in the STM by the READ operation, production 5 will be executed. This results in FOOD SHORTAGE being marked as OLD. This prevents the system from counting FOOD SHORTAGE twice, since FOOD SHORTAGE and (OLD FOOD SHORTAGE) are not the same. The production also reaults in a MARK being placed in STM. If at any time, Kaddafi has supported four radical foreign causes with no noticable achievement, production 7 is executed, which results in all four supports of radical foreign causes being marked as old, and the addition of a MARK to the STM. If it happens that there is an increase in skilled labor when there is also

a MARK in STM, both the skilled labor increase and the MARK are masked. In essense, one of the strikes is erased -- although it still takes up a position in the STM. If at any time, Kadafi has managed to accumulate four MARKS, the symbol REQUEST will be placed in STM. This results in the Revolutionary Command Council asking Kadaffi for his resignation.

This production system is a better illustration of the presense of the control structure than was the previous one. Notice that all of the productions that erase 'marks' from the STM are at the end of the system. This means that a mark can only be erased if there are no 'bad things' in the STM. If the set of productions that erased marks were to be moved to the top of the system, the chance for an erasure would be greater (and the chance for removal less). If production 3 were placed at the end, the only time that Kadaffi would be asked to step down would be when neither anything good or bad was happening. If it were inserted after production 11, the only time that he would be asked to go the desert is when he had accumulated four strikes, and at the present time all was going well, i.e., the short term memory was filled either with junk or positive symbols. Depending upon the sorts of things that the Council could be expected to receive from the environment, by rearanging the individual productions, the chance that Kadaffi would be requested to step down could ba varied. Thus it is not enough to say that fiscal irresponsibility and food shortages count against Kadaffi in the eyes of the Council. One must be more specific about exactly what the conditions are that will cause the Council to request his removal.

This completes the general discussion of production systems. Before going on to discuss the role of language and the notion of a grammar, it would be useful to discuss a little more fully how we intend to structure the production systems for the decision modules of the five countries, and

exactly what properties we feel must be represented in the productions if they are to be of use in the generation of reasonable forecasts of behavior. As was discussed above, one of the prime assumptions we are making about nations is that they react to a perceived environment. All nations are at least in principle capable of recieving the same observations from the environment. But nations do not all react the same way to environmental conditions. In addition to the fact that there are obvious distinctions according to the face of the issue (the oil embargo was favored by the oil producing Arabs, or Saudi Arabia is in favor of lower oil prices but Iran is not) there are also cases of misperception. If the decision modules for the various countries are to be capable of making such distinctions, they must have some capacity to take incoming messages from the environment and interpret them according to the beliefs, presumptions, presuppositions, and biases peculiar to the decision makers in each of the countries. Thus based upon the contents of the STM of the national decision system, elements recalled form long term memory, and Newell's invariant processing routines, the system must decode the raw stimulus or message into the cognitive map of the decision makers. The production system must also have the capability to rewrite the goals of the system based upon experience according to some predefined process. The production system must have the capability of rewriting the perceptual coding rule, and well as changing those features of the environment to which the decision mechanism is attentive. The production rules must allow the generation of responses to incoming messages from the environment. The productions should invoke a cognitive image of the environment in its attempts to determine appropriate reactions. In other words, the production systems must be able to make decisions. The system must take incoming messages about the status of the environment, interpret these inputs according to the peculiarities of the decision system,

evaluate the current goal satisfaction, make trade-off decisions about resource investment towards the achievement of certain goals, determine appropriate actions that will increase the amount of goal satisfaction, and put those actions into operation. At the same time, the system must evaluate goals and their achievement and make appropriate changes in the goal structure. As was mentioned in the section on multi-goaled decision making, we intend to embed the goals and their rewrite rules (change process) directly within the production system rather than conceptualize it as a separate and independent structure. Another structural decision that we have made is not to treat the nation as a single decision system, but rather introduce some of the notions of bureaucratic politics (Allison 1971; Allison and Halperin 1972; among others) into the decision process. The finest level of detail that we anticipate including in the simulation is bureaus or ministries. The detail required to model specific individuals would be too great and would probably not add any accuracy to the final product -- the error factor in the specification of the individual characteristics would be fairly high. This is not to say that we will ignore specific individuals where they have a strong influence on the operation and outputs of various sub-structures in the national bureaucracy.

As the project is currently conceptualized there are essentially two types of communication linkages that must be dealt with: 1) the linkage between the national decision system and the environment; and 2) the internal communication between the various bureaus and ministries. The first is essential since the decision mechanism must have some means for determining the current status of goal achievement and it must be capable of effecting the environment with its actions. If we are to model the national decision system as a composite bureaucracy, the various levels in the bureaucracy must have the capability of communicating with each other. We propose to create these

linkages by means of a language and its associated grammar -- a language of policy behavior and a language of internal directives and communications.

The Role of Language and a Grammar

When we communicate with another person or a computer we do so by using a set of symbols that we both are able to perceive, and in addition only certain strings of those symbols make sense (or convey the intended meaning). We can't communicate with a computer by shouting at it, since it cannot perceive our attempts to communicate. In addition we can't just tell it anything, since it has the capability of making sense out of very specific strings of special symbols. The system that we use to communicate is called a language, the symbols are elements of the alphabet of that language, and the rules for forming possibly intelligible strings of symbols is called a grammar. The grammar will not insure that the meaning that was intended is actually conveyed, since others can misinterpret what we had intended. It is also the case that the context in which the sentence is communicated will affect the meaning. Even though the sentence: "My dog has fleas" is grammatical, if we were to walk up to a stranger and utter that sentence, he would not know what we were talking about. The sentence "Green dreams sleep quietly." might be considered a grammatical sentence but it does not make sense in any context. The basis for communication is a language, and the rules for creating acceptable sentences in that language is the grammar. What we intend to do is to construct a language and its associated grammar for the specification of the behaviors of the national decision systems. The only actions that the systems will be capable of generating will be grammatical sentences in the language that we specify. Any information that enters the national decision system must be a grammatical sentence in the language or else the system cannot decode the string of symbols to determine its meaning.

communications between the various parts of the decision system must also be in the proper form or no meaning will be conveyed. Any actions that a nation takes in attempting to control its environment must be in the proper form if it is to have any impact on the environment (one cannot just tell inflation to go away) and if other nations or actors in the system are to be able to understand the action.

This notion of a grammar is really not as alien to the field of international relations as first might be imagined. One of the main sources or types of data that has been used in the field is events data. (McClelland and Young 1969, Hermann et. al. 1974). Events are actions by national decision systems, and events data simply represents the coding of these actions a single coding scheme, generally of the form: action, actor, target. Language is very much like a coding scheme. It is the representation (coding) of meaning according to a set of rules (a grammar). Our approach to the representation of action differs from the standard events data approach in two respects. The first difference is in the level of detail (the information content of the event). A common events coding category is official diplomatic protest. While there has been some effort to also include in the coding scheme the context of the protest, in all cases almost all of the actual content (what the protest was about) has not been coded. While we can conceive of situations in which one could make sense out of correlations between event type categories, we find it impossible to begin to build a process model of international relations in which the only means of communication between the various national bureaucracies is by contentless statements. In order to go beyond the type of theorizing that says that if a nation receives a diplomatic protest it will respond with an unofficial warning and an armed force mobilization, exercise and/or display (to use two of the categories from WEIS), a different sort of language will be

required. That language must have content (meaning) as well as form (the type of action). Since we take seriously our assumption that nations are goal seeking systems, it is imperative that the language that "nations talk with" be able to express the goals of the decision makers. While Callahan's (1974) analysis of the goals of the five oil producing nations identified a wide range of goals, none of the goals that he identified were of the form: "Decrease the number of formal diplomatic protests by three-fourths." We need a language capable of expressing a much richer content than any of the existing event category schemes are capable of providing. The second difference between typical events coding and our language building efforts stems primarily from our assumption that nations perceive incoming messages within the context that they are generated, and from our desire for a comparatively rich language for the expression of national decision outputs. The standard approach followed by all existing events data efforts is the use of the coding category for the interpretation of actions. There is an explicit attempt to make perceptual decisions. Common categories include threats, accusations, and rewards. It is our predilection to leave the perception of the meaning of the actions to the decision system. We want our language to be as neutral as possible. What is a negative deed from the perspective of one nation may be a very desirable action as far as some other nation is concerned. This perceptual role in the standard approach to the recording of international interactions is handled by the coders, who are assigned with the responsibility of making the distinction between a threat and a promise. (A threat is really nothing more than a promise with a negative consequence.) We want the nations to make that distinction.

If the language is to be a neutral affair intended only for the transmission of ideas and not predetermined perceptions by some third party the

language must be structured so as to avoid the gross pre-processed perceptual categories of the standard events data approach. This implies that the basic units of the language should be statements of action rather than perceptual categories. It will then be up to the perceptual portion of the decision system to parse the action message into its own cognitive map or conceptual categories. This is not to say that the word "threat" cannot appear in the language, but that it will be the job of the decision system to determine whether it really is a threat, the consequences the action will have on the goals for the system, as well as the credibility of the action. This conception of the role of the language has some implications for the structure of the language, the second distinction between events coding schemes and our approach. The manner in which events people have approached the structure of their coding categories is to devise a mutually exclusive and collectively exhaustive typology for the classification of international interactions. In essence they have listed all of the possible sentences in their language. They then look at the event or interaction and determine which of the sentential forms fits the action. Our approach differs from this approach in that we have elected to specify rules for generating sentences in the language rather than listing them individually. If one has a small language capable of having only a few sentences, the list approach has some merit. On the other hand, if the language is large and capable of expressing a wide variety of sentences, some of which may be appropriate only in certain circumstances, i.e., My dog has fleas, the exhaustive listing of all sentences may be impossible. These rules for generating sentences in a language is called a grammar. The rules of grammar for English specify what words may follow other words. Thus if we had a dictionary of all of the words in the English language, and if we had all of the rules for generating acceptable sentences, it would be in

principle possible to generate all sentences that could ever be spoken in English. Not all of them would make sense (Green dreams sleep quietly). Grammatical sentences are not necessarily sentences that make sense; grammar does not determine meaning, only form. (As with the perceptual aspects, it would be the responsibility of the decision module to determine appropriate sentences.) The way that formal linguists generally express it is that a grammar is the set of rules specifying admissible manipulations (stringing together) of the words of language. By taking a finite set of words and a finite set or rules, it is possible to generate an infinite number of sentences. The advantages of listing the rules over listing all possible sentences is substantial. By basing our language on a modest set of objects (actions and actors) on a small set of rules, we will be able to develop a language of greater precision, breadth, depth, complexity, and richness that could be hoped to be generated by coming up with a list of possible sentences. We will have a more complex, conceptually leaner, and theoretically powerful system for expressing the behavior of a nation than an event coding typology could ever hope to generate.

We are placing some very large demands upon our language. It must be able to describe a context that will allow the perceptual system of the decision modules to determine meaning; it must be able to describe the current state of the environment so that a decision can be made; it must be medium by which the actions of a nation can be transmitted between and within nations. In fairness to those who have taken the events coding approach, it should be mentioned that our demands upon the language are much more severe than those of the events people. They wish only to describe very gross types of behavior, while we have to express not only the type of behavior, but also the substance of the act. While we are making more

severe demands of our language, because of the conceptual power of the approach to language building through a grammar, the task in some ways is simplified. Because of the approach that we are taking we can break the entire problem down into manageable hunks. Rather than being forced to consider the language as a whole, we can break it down into the problems of a grammar, sentential forms, and objects.

As crude example of the power of approach, consider the specification in Figure IV. Structurally, this list of six sentence forms is sufficient to express all 63 of the WEIS (McClelland and Young, 1969) coding categories. For example, sentence for 5 would be coded as a threat, promise, the offer or a proposal, a demand, a warning, or an ultimatum (to use some of the WEIS categories). The scheme does have the major shortcoming of not having listed the actors and most importantly the actions, but it does, at least at a structural level, show that a simple schema can reproduce event typologies. The language as specified in Figure IV is defficient in other several respects. It is not r[illegible] enough to serve as the basis for the language that we need -- sentences of the form of questions are not included as well as sentences of the form X will give A to Y in order for Y to B to Q (The United States give military assistance to Israel to stem Syrian aggression). But even this simple scheme has the capability of generating sentence structures that are much more complex than WEIS or any other event coding schema attempts to specify. For example the sentence: Since X will not do A then if X does B, Y will do C. This sentence represents the embedments of sentence type 1 in type 6. It is this ability of the grammar to define embedments in a recursive manner that accounts for its generality and power. While this scheme is insufficient for the specification of the language, it does illustrate that the approach has the ability to express both the substance and form of international

activity.

In addition to the specification of a language that is suitable for the expression of the output of the decision process, we are in the process of determining whether or not the language that serves as a communication medium between the various bureaucratic parts requires a structure that is in some manner different from that used for the conveying of final decisions. While it is too early to report on that effort, it does seem that there are different requirements for this internal language. Whether or not a new structure will be required is unknown at this time.

One of the very powerful aspects of this effort at specifying a language for the communication of the decisions of national decision systems is the potential linkage with current events data collection efforts. While our basic approach is somewhat different there is a very important linkage between the two types of efforts. If we are successful, we should be in a position to generate a data source that would be expressible in an event type coding typology. We should be able to generate the raw data of events data collection efforts. This fact has two important implications: 1) our approach is not alien to much of the work now being done in the field of international relations; and 2) existing events data collections can serve as an important source of validating data. It should be possible to take the output from the simulations (sentences in the language) and code them according to an events coding typology. That coding could be compared to current data sets to assess the amount of agreement. This interface between events data and our efforts at the specification of language also has the implication that propositions that we generate could be translated into event type propositions. Thus there is a potential source of mutual benefit.

Another very important aspect of our efforts is that the language and

the technique of specifying the decision process as a production system will not be limited only to the Middle East. It will serve as a means for the specification of the decision process and decision outputs for any country. This aspect coupled with the interface with events data efforts should represent not only a substantial increase in our understanding of the Middle Eastern situation, but also a potential means for increasing our knowledge about the international relations of nations in general.

Summary and Overview

When fully specified, we conceive that the decision module (structured as a production system) will receive strings of symbols (sentences in the language) from the environment. The decision module will take these input strings and according to the rules of the grammar and the perceptual rules written in the production system, will parse the input strings to determine their meaning. This picture of the environment that the system has perceived will then be evaluated with respect to the goals that the system has for the environment. Based upon the model that the nation has for how the world works (its model of the environment) it will determine behaviors (other sentences in the language) that it thinks appropriate for controlling the environment. Besides the output of final decisions, the decision module will also make changes in it goal structure and update its model of the environment based upon past experience. We also anticipate that the decision module will be structured so as to include various bureaucratic actors. It will be the interaction of these various sub-structures that will in the final analysis determine the behavior of the national decision system.

The first portion of this report has laid out the issues that we see as relevant to the specification of the decision system. These issues include the areas of general goal seeking systems and problems peculiar to

multi-goal seeking systems. The second portion of the report represents a discussion of the structure within which we propose to resolve these issues. Our approach consists of the specification of the process of decision making as a production system. The notion of a grammar and language was introduced to handle the problems of communication between nations as well as within nations. The importance of the language concept becomes especially relevant with our assumption that nations are goal seeking perceptual systems.

The work that remains to be done falls into three groups: 1) the further specification of the issues that must be resolved; 2) the specification of more complex production systems that incorporate the notions of multi-goal seeking systems; and 3) the specification of an acceptable language for the communication of decisions. While there is much to be done, the fact that we have been able to identify somewhat separable issue clusters should promote the attainment of our final goal, the production of reasonable forecasts of the behavior of the five oil producing Middle East nations.

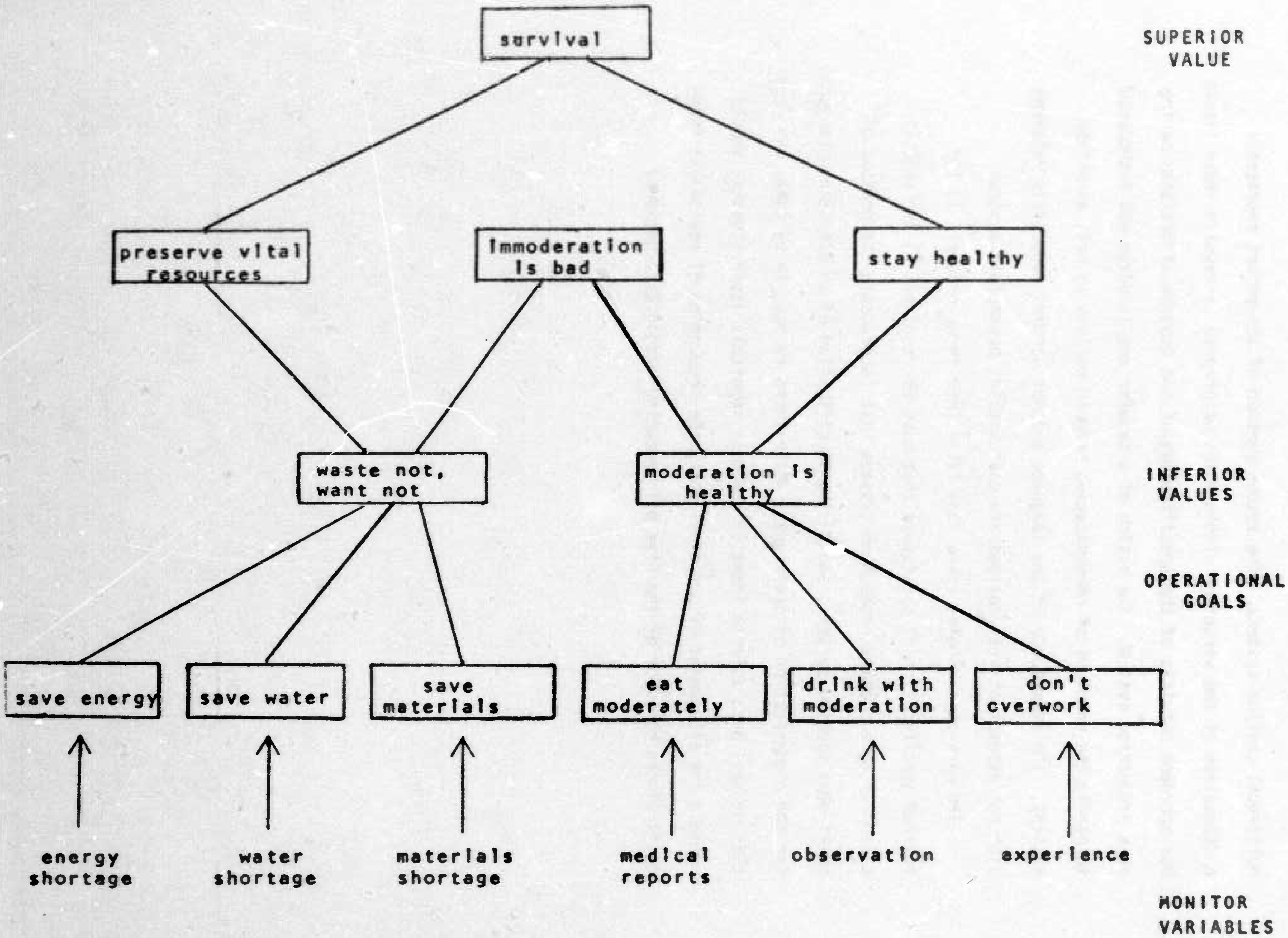


Figure 1 - Sample Norms Structure

FIGURE II

1: (AA AND BB → (OLD **))

2: (CC AND BB → (SAY HI))

3: (DD AND (EE) → BB)

4: (AA → CC DD)

5: STM(AA QQ (EE FF) RR SS)

(from Newell 1973b: 466)

FIGURE III

1: (STOP) → END

2: (REQUEST) → (OUTPUT "GO TO DESERT", STOP)

3: (MARK,MARK,MARK,MARK) → (OLD(**),REQUEST)

4: (FOOD SHORTAGE,FISCAL IRRESPONSIBILITY,NEGATIVE FOREIGN COMMENT BY AN ALLY) → (OLD (**), REQUEST)

5: (FOOD SHORTAGE) → (OLD(**),MARK)

6: (SUPPORT OF RADICAL FOREIGN CAUSES,NO ACHIEVEMENT) → (OLD(**),MARK)

7: (SUPPORT OF RADICAL FOREIGN CAUSES,SFRC*,SFRC,SFRC) → (OLD(**), FISCAL IRRESPONSIBILITY)

8: (FISCAL IRRESPONSIBILITY) → (OLD(**),MARK)

9: (NEGATIVE FOREIGN COMMENT BY AN ALLY → (OLD (**), MARK)

10: (BAN BROTHELS or BAN CIGARETTES or BAN ALCHOHOL or BAN LUXURYS) → (OLD(**), ORTHODOXY)

11: (ORTHODOXY,ORTHODOXY,ORTHODOXY,ORTHODOXY) → (OLD(**),MARK)

12: (FOOD SURPLUS,MARK) → (OLD(**))

13: (SUPPORT RADICAL FOREIGN CAUSES,ACHIEVEMENT,MARK) → (OLD(**))

14: (INCREASE IN SKILLED LABOR,MARK) → (OLD(**))

15: (SADAT HAS TROUBLES,MARK) → (OLD(**))

16: → READ

* SFRC = SUPPORT OF RADICAL FOREIGN CAUSES

FIGURE IV

1 <actor> <will | will not> do <action>*,**

2 <actor> <should |should not> do <action>

3 <actor> <did |did not> do <action>

4 <actor> <does| does not> do <action>

5 if <1,2,3,4,5,6,> then <1,2,3,4,5,6,> ***

6 since <1,2,3,4,5,6,> then <1,2,3,4,5,6,>

* The actor and action terms refer to a list (not shown) of acceptable action types and acceptable actors.

** Vertical bar means that one of the options is to be selected.

*** The number within the brackets refer to the numbers associated with the sentence types.

REFERENCES

Allison, Graham T. (1971), Essence of Decision: Explaning the Cuban Missle Crisis. Boston: Little Brown.

Allison, Graham T., and Morton H. Halperin (1972), "Bureaucratic Politics: A Paradigm and Some Policy Implications," in Raymond Tanter and Richard H. Ullman (eds), Theory and Policy in International Relations. Princeton: Princeton University Press, 40-79.

Bossel, Hartmut and Barry B. Hughes (1973), "Simulation of Value-Controlled Decision-Making: Approach and Prototype." Institut fur Systemtechnik und Innovationsforschung: Karlsruhe, Germany.

Callahan, Patrick T. (1974), "An Analysis of the Goals of Five Oil Producing Nations," Project for Theoretical Politics Research Report 14, Ohio State University.

Deutsch, Karl (1966), The Nerves of Government. New York: The Free Press.

Hemple, Carl (1959), "The Logic of Functional Analysis," in Llewellyn Gross (ed), Symposium on Sociological Theory. New York: Harper and Row, 271-307.

Hermann, Charles F., M. East, M. Hermann, B. Salamore, and S. Salamore (1974), CREON: A Foreign Events Data Set. Beverly Hills: Sage.

Holsti, Ole R. (1965), "The 1914 Case," American Political Science Review, 59: 365-378.

Holsti, Ole R., Richard A. Brody, and Robert C. North (1965), "The Management of International Crisis: Affect and Action in American -- Soviet Relations." Journal of Peace Research, 3-4: 170-190.

Holsti, Ole R., Robert C. North, and Richard A. Brody (1968), "Perception and Action in the 1914 Crisis." in J. David Singer (ed), Quantitative International Politics. New York: The Free Press, 123-159.

Klahr, David (1973), "A Production System for Counting, Subitizing, and Adding," in William G. Chase (ed), Visual Information Processing. New York: Academic Press, 527-546.

McClelland Charles, and R. A. Young (1969), "World Event/Interaction Survey Handbood and Codebook." WEIS Technical Report 1, University of Southern California.

Miller, G. A., E. Galanter, and K. Pribram (1960), Plans and Structure of Behavior. New York: Holt, Reinhart, and Winston.

Nagel, Ernest (1956), Logic without Metaphysics. Glencoe, Il: Free Press.

REFERENCES -- 2

Nelson, Richard R. and Sidney G. Winter (1972), "Toward an Evolutionary Theory of Economic Capabilities," Institute of Public Policy Studies Discussion Paper 44: University of Michigan.

______________ (1973), "Neoclassical vs Evolutionary Theories of Ecomonic Growth: Critique and Prospectus," Institute of Public Policy Studies Discussion Paper 46: University of Michigan.

Nelson, Richard R, Sidney Winter, and Herbert Schuette (1973), "Technical Change in an Evolutionary Model." Institute of Public Policy Studies Discussion Paper 46: University of Michigan.

Newell, Allen (1966), "On the Representation of Problems." Computer Science Research Review, 1966, 18-33.

__________ (1973a), "You Can't Play 20 Questions with Nature and Win." in William G. Chase (ed), <u>Visual Information Processing</u>. New York: Academic Press, 283-310.

__________ (1973b), "Production Systems: Models of Control Structures." in William G. Chase (ed), <u>Visual Information Processing</u>. New York: Academic Press, 436-526.

Newell, Allen and Herbert Simon (1972), <u>Human Problem Solving</u>. New York: Prentice-Hall.

North, Robert C., Ole Holsti, George Zaninovich, and Dina Zinnes (1963), <u>Content Analysis: A Handbook with Applications for the Study of International Crisis</u>. Evanston: Northwestern University Press.

Rummel, R. (1971), "Status Field Theory and International Relations." DON Research Report 50, University of Hawaii.

Simon, Herbert (1955), "A Behavioral Model of Rational Choice," Quarterly <u>Journal of Economics</u>, 69, (Feb), 99-118.

__________ (1969) <u>The Sciences of the Artificial</u>. Boston: MIT Press.

Singer, J. David (1972), "The Correlates of War Project: Interim Report and Rationale." World Politics, 24 (Jan), 243-270.

Snyder, Richard, H.W. Bruck, and B. Sapin (1963) (eds), <u>Foreign Policy Decision Making</u>. New York: The Free Press.

Sprout, H., and M. Sprout (1956), "Man - Milieu Relationship Hypothesis in the Context of International Politics." <u>Foreign Policy Analysis Series</u>:3. Princeton: Princeton University Press.

______________ (1965), <u>The Ecological Perspective on Human Affairs</u>. Princeton: Princetion University Press.

REFERENCES -- 3

Thorson, Stuart (1972), "National Political Adaptation in a World Environment." Project for Theoretical Politics Research Report 10, Ohio State University.

Weiner, Norbert (1961), Cybernetics. New York: John Wiley and Sons.